

CHAPTER 4

Water Quality

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Tahoe Regional Planning Agency's Resolution 82-11 established Water Quality Threshold Standards for six major indicator themes, including: 1) Lake Tahoe pelagic (deep) waters, 2) Lake Tahoe littoral (nearshore) waters, 3) tributaries, 4) direct surface runoff and stormwater discharge to surface waters, 5) stormwater discharge to groundwater, and 6) other lakes (i.e., lakes in the Tahoe Basin other than Lake Tahoe). Nutrients supporting algal growth (nitrogen and phosphorus) and suspended sediment (including fine particles) are the primary pollutants of concern in the Basin because of the impact on Lake Tahoe transparency, and many components of the aquatic system are thought to be adversely affected by these pollutants (Reuter et al. 2009).

The *Bi-State Compact* requires the *Regional Plan* to provide for the attainment and maintenance of federal, state, or local water quality standards. Resolution 82-11 sets out Numerical Standards, Management Standards, and Policy Statements for water quality. Some of these Threshold Standards are referenced to state standards. In other cases, references to conditions for specific periods are identified and targeted, and can be found in the Study Report for the Establishment of Environmental Threshold Carrying Capacities (TRPA 1982b). The value statements TRPA used in setting the Threshold Standards and management targets for water quality were:

- Attain levels of water quality in the lakes and streams within the Basin suitable to maintain the identified beneficial uses of Lake Tahoe
- Restrict algal productivity (rate of growth) to levels that do not impair beneficial uses or deteriorate existing water quality conditions in the Lake Tahoe Basin
- Prevent degradation of the water quality of Lake Tahoe and its tributaries to preserve the Lake for future generations
- Restore all watersheds in the Basin to reflect natural hydrologic conditions and functions such that runoff is treated by natural process rather than engineered solutions

This chapter presents an evaluation of available data on water quality conditions and trends for the Tahoe Basin's aquatic system, relative to TRPA Threshold Standards and applicable state and federal water quality standards (Table 4-1). Previous Threshold Evaluations have categorized water quality standards according to the Basin's aquatic system components, and this evaluation uses the same approach. Specifically, each aquatic system component is treated as an Indicator Reporting Category; indicators for relevant standards are grouped within each category. Unfortunately, current and consistently collected data (i.e., consistent data collected between 2006 and 2010) were insufficient to analyze status and trends (and thus specifically address attainment status) for Lake Tahoe's littoral zone, stormwater runoff to surface water, stormwater runoff to groundwater, and other lakes. Previous Threshold Evaluations (TRPA 2001, TRPA 2007) and reports (Lico 2004, NDEP 2004, 2nd Nature 2006,

NDEP 2009, Lahontan and NDEP 2010, TERC 2011a) provide an evaluation and summary of available data related to these water quality topics.

For the nearshore (littoral zone), an effort is currently underway to synthesize existing monitoring data and research findings (Alan Heyvaert, Lead Scientist, Desert Research Institute, personal communication). This research was initiated because contemporary monitoring and research indicates conditions in the Lake Tahoe's nearshore may be in decline; specifically, the decline in native fish abundance, and increase in the distribution and abundance of nearshore periphyton (attached) algae and aquatic invasive species (Ngai et al 2011, TERC 2011a). The results of this synthesis effort will be reported when the project is completed (presumably at or before June 2013). Consequently, evaluations of these specific indicators are not included in this chapter, but will be reported in future TRPA reports.

Generally, the analyses and information presented in this chapter do not investigate the mechanisms or processes driving the observed status and trends, or alternative hypotheses to explain the observations. That is, this document does not definitively investigate the causes and effects resulting in the observed status and trends. There are two reasons for this: 1) the analytical approach, regression analysis, employed throughout this Threshold Evaluation is not necessarily the appropriate tool to explore cause and effect. Although regression analysis can be used to indicate the trajectory of change between two variables (i.e., trend), regression analysis is most commonly used to test for correlations among variables, and inform us about the strength of those correlations; 2) investigation and presentation of the mechanisms and processes driving observed status and trends is beyond the charge given to the five-year Threshold Evaluation and are discussed in other reports. Other efforts have extensively explored mechanisms driving Lake Tahoe conditions (LRWQCB and NDEP 2008a, 2008b, 2008c). The purpose of Threshold Evaluations is to document and describe the status and trends of relevant indicators relative to established standards, and then assess the condition of the environment and resources in the Tahoe Region. Investigations of the underlying mechanisms and processes driving observed status and trends are more appropriate as part of focused synthesis evaluations, to determine if new or modified Threshold Standards and indicators are warranted.

That being said, several external and internal factors are known to affect the water quality of the Basin's aquatic system, such as precipitation, air quality, atmospheric deposition, land use intensity, impervious cover (e.g., pavement and buildings), urban stormwater runoff, and soil disturbance (Coats 2004, Coats et al 2008, Lahontan and NDEP 2010). Although many of these factors are evaluated individually in other chapters of this report, it is fully acknowledged that strong linkages exist among these factors. The conditions we observe in the Tahoe Region are due to multiple—and often complex—interactions among a variety of natural and anthropogenic forces. It is beyond the scope of this chapter to include an in-depth review of the external and internal factors affecting Tahoe Basin water quality, but Reuter et al. (2009) have developed conceptual models for Tahoe Basin water quality, which is described here as a helpful overview.

Prior to the arrival of European settlers, the Lake Tahoe Watershed was thought to have operated as a heterogeneous hydrologic system. Precipitation (both snow and rain) was distributed broadly through a variety of natural conditions defined by natural topography, habitat structure, soil and ground cover, and local meteorology. Natural features in the catchment determined the degree of surface water infiltration and surface ground-water interactions. Fire, floods, and other natural disturbances (e.g., earthquakes, landslides, or avalanches) were the major forces of disturbance and could generate major releases of pollutants such as fine sediment and nutrients. However, these were likely episodic in nature, with potentially substantial intervening periods between major events. More regular, low-

intensity fires and a mature forest likely translated into low-nutrient stores on the forest floor. These were the watershed conditions that supported an ultra-oligotrophic Lake Tahoe: a lake with a sustained level of exceptional water clarity (≥ 30 m), a lake receiving low inputs of nutrients and therefore supporting low levels of primary productivity, and a lake containing a relatively simple food web that may have substantially relied on the recycling of nutrients and carbon, rather than new inputs from the surrounding watershed.

Urbanization and other forms of infrastructure development in the Tahoe Basin since the mid-1800s have contributed to a change in the natural hydrologic routing in many catchments. Development has also resulted in areas of land disturbance and impervious cover, which directly affects runoff dynamics and inhibits stormwater infiltration. With this development comes a hydrologic system that tends to concentrate surface runoff and inhibit surface water-groundwater interactions. Studies completed as part of the Lake Tahoe TMDL show disproportionately higher loads of fine sediment and nutrients (pollutants known to impact Lake clarity) coming from the urban-related land uses (LRWQCB and NDEP 2008a, 2008b, 2008c). Much of the urban development has occurred along the edge of Lake Tahoe, meaning that in many cases, there is little or no buffer between the highest source of pollution and the Lake. Activities associated with development and development itself, primarily inside the Basin, is now thought to be responsible for many of the primary and secondary drivers of water quality (Figure 4-1).

From a water quality perspective, our contemporary understanding of the Lake Tahoe watershed is framed around the “pollutant pathway” concept. This concept follows a logical sequence of pollutant generation, transport, fate, and system response including: 1) source identification, 2) transport within the watershed, 3) pollutant control and abatement, 4) loads to tributaries and the Lake, 5) fate of pollutant material in the lake, and 6) assessment of water quality response. A water quality conceptual model illustrating this contemporary understanding is presented schematically in Figure 4-1. This diagram is not intended to identify all the drivers nor show all the linkages associated with water quality in the Tahoe Region. Instead the objective is to highlight important aspects of the “pollutant pathway,” including the routes and linkages among those pathways.

Table 4-1. Water quality standards for the Tahoe Basin aquatic system organized by the six major components of the Tahoe Basin's aquatic system. Each component is considered a separate Indicator Reporting Category.

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
Pelagic Lake Tahoe	Nitrogen loading	Numerical	Reduce dissolved inorganic nitrogen (N) loading from all sources by 25% of 1973-81 annual average	Annual Mean Total Nitrogen Concentration \leq 0.15 - 0.23 mg/L depending on the water body.	Total annual load	Concentration: milligrams/liter (mg/L) Load: kilograms/year (kg/yr)
	Phytoplankton primary productivity	Numerical	Achieve the following long-term water quality standard: Annual mean phytoplankton primary productivity: 52gmC/m ² /yr.	None	grams Carbon/m ² /yr.	grams/m ² /yr.
	Secchi disk transparency	Numerical	Achieve the following long-term water quality standard: Winter (December - March) mean Secchi disk transparency: 33.4m.	Transparency - Annual mean Secchi disk transparency: 29.7m (CA State standard) Clarity-Vertical Extinction Coefficient (NV State Standard)	Secchi disc depth	Meters (m)
	Recognition of Threshold Standard exceedance	Policy	This threshold [numeric standard] is currently being exceeded and will likely continue to be exceeded until sometime after full implementation of the loading reductions prescribed by the thresholds.	N/A	N/A	N/A

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
	Pollutant loading	Management	Reduce the loading of dissolved phosphorus, iron, and other algal nutrients from all sources as required to achieve ambient standards for primary productivity and transparency.	Annual mean total phosphorus concentration \leq 0.005-0.015 mg/L, depending on the water body. Annual mean iron concentration \leq 0.01-0.03 mg/L, depending on the water body.	Total annual load	Concentration: mg/L Load kg/yr
	Pollutant loading	Management	Reduce dissolved inorganic nitrogen loads from surface runoff by approximately 50 percent, from groundwater approximately 30 percent, and from atmospheric sources approximately 20 percent of the 1973-81 annual average. This threshold relies on predicted reductions in pollutant loadings from out-of-basin sources as part of the total pollutant loading reduction necessary to attain environmental standards, even though the Agency has no direct control over out-of-basin sources. The cooperation of the states of California and Nevada will be required to control sources of air pollution which contribute nitrogen loadings to the Lake Tahoe Region.	Annual Mean Total Nitrogen Concentration \leq 0.15 - 0.23 mg/L depending on the water body.	Total annual load	Concentration: mg/L Load kg/yr

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
Littoral Lake Tahoe	Nitrogen loading	Numerical	Reduce dissolved inorganic nitrogen (N) loading from all sources by 25% of 1973-81 annual average	Annual Mean Total Nitrogen Concentration \leq 0.15 - 0.23 mg/L depending on the water body.	Total annual load	Concentration: mg/L Load kg/yr
	Pollutant loading	Numerical	Reduce the loading of dissolved inorganic nitrogen, dissolved phosphorus, iron, and other algal nutrients from all sources to meet the 1967-71 mean values for phytoplankton primary productivity and periphyton biomass in the littoral zone.	Annual Mean Total Nitrogen Concentration $<$ 0.15 - 0.23 mg/L depending on the water body. Annual mean total phosphorus concentration $<$ 0.005-0.015 mg/L, depending on the water body. Annual mean iron concentration $<$ 0.01-0.03 mg/L, depending on the water body.	Total annual load	Concentration: mg/L Load kg/yr
	Sediment loading	Numerical	Decrease sediment load as required to attain turbidity values not to exceed three NTU. In addition, turbidity shall not exceed one NTU in shallow waters of the Lake not directly influenced by stream discharges	None	Turbidity	Nephelometric Turbidity Unit (NTU)

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
	Pollutant loading	Management	Reduced dissolved inorganic nitrogen loads from surface runoff by approximately 50 percent, from groundwater approximately 30 percent, and from atmospheric sources approximately 20 percent of the 1973-81 annual average. This threshold relies on predicted reductions in pollutant loadings from out-of-basin sources as part of the total pollutant loading reduction necessary to attain environmental standards, even though the Agency has no direct control over out-of-basin sources. The cooperation of the states of California and Nevada will be required to control sources of air pollution which contribute nitrogen loadings to the Lake Tahoe Region.	Annual Mean Total Nitrogen Concentration $\leq 0.15 - 0.23$ mg/L depending on the water body.	Total annual load	Concentration: mg/L Load kg/yr

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
Tributaries	Attain applicable State Standards	Numerical	Attain applicable State standards for concentrations of dissolved inorganic nitrogen, dissolved phosphorus, and dissolved iron. Attain a 90 percentile value for suspended sediment concentration of 60 mg/L.	California standard: Attain a 90th percentile value for suspended sediment concentration of 60 mg/L. Annual Mean Total Nitrogen Concentration < 0.15 - 0.23 mg/L depending on the water body. Annual mean total phosphorus concentration < 0.005-0.015 mg/L, depending on the water body. Annual mean iron concentration < 0.01-0.03 mg/L, depending on the water body. Nevada standard: Annual mean total phosphorus concentration \leq 0.05 mg/L.	Same as most stringent State standard. Proportion of individual measurements that exceed 60 mg/L of suspended sediment	Milligrams/Liter (mg/L) for nutrients; percentage of individual measurements exceeding 60 mg/L for sediment
	Total annual nutrient and suspended sediment loads	Management	Reduce total annual nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe	Annual mean total concentration of nitrogen, phosphorus, and suspended sediment	Total annual load	Concentration: mg/L Load kg/yr

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
Surface Runoff (discharge to a water body)	Nutrient concentrations	Numerical	Achieve a 90 percentile concentration value for dissolved inorganic nitrogen (DIN) of 0.5 mg/L, for dissolved phosphorus (DP) of 0.1 mg/L, and for dissolved iron (DI) of 0.5 mg/L in surface runoff directly discharged to a surface water body in the Basin.	Annual Mean Total Nitrogen Concentration < 0.15 - 0.23 mg/L depending on the water body. Annual mean total phosphorus concentration < 0.005-0.015 mg/L, depending on the water body. Annual mean iron concentration < 0.01-0.03 mg/L, depending on the water body.	Proportion of individual measurements that exceed 0.5 mg/L (DIN), 0.1 mg/L (DP), and 0.5 mg/L (DI)	Percentage
	Sediment concentrations	Numerical	Achieve a 90 percentile concentration value for suspended sediment of 250 mg/L.	Attain a 90th percentile value for suspended sediment concentration of 60 mg/L.	Proportion of individual measurements that exceed 250 mg/L	Percentage
	Total annual nutrient and suspended sediment loads	Management	Reduce total annual nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe	Reduce loads of fine sediment particles, total nitrogen, and total phosphorus as established by Lake Tahoe TMDL	Total annual load	kg/yr

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
Groundwater (discharge to)	Surface runoff infiltration	Management	Surface runoff infiltration into the groundwater shall comply with the uniform Regional Runoff Quality Guidelines as set for in Table 4-12 of the Draft Environmental Threshold Capacity Study Report, May, 1982.	California standard: Attain a 90th percentile value for suspended sediment concentration of 60 mg/L. Annual Mean Total Nitrogen Concentration < 0.15 - 0.23 mg/L depending on the water body. Annual mean total phosphorus concentration < 0.005-0.015 mg/L, depending on the water body. Annual mean iron concentration < 0.01-0.03 mg/L, depending on the water body. Nevada standard: Annual mean total phosphorus concentration \leq 0.05 mg/L.	Maximum concentration of constituent in waters infiltrated into soils: Total nitrogen = 5 mg/L; total phosphate = 1 mg/L; iron = 4 mg/L; turbidity = 200 NTU; grease and oil = 40 mg/L.	mg/L or NTU

Indicator Category	Name of Standard	Standard Type	Adopted TRPA Threshold Standard (Resolution 82-11)	Applicable State and Federal Standards	TRPA Indicator	Unit of Measure
	Surface-groundwater connection	Management	Where there is a direct and immediate hydraulic connection between ground and surface waters, discharges to groundwater shall meet the guidelines for surface discharges, and the Uniform Regional Runoff Quality Guidelines shall be amended accordingly.	California standard: Attain a 90th percentile value for suspended sediment concentration of 60 mg/L. Annual Mean Total Nitrogen Concentration < 0.15 - 0.23 mg/L depending on the water body. Annual mean total phosphorus concentration < 0.005-0.015 mg/L, depending on the water body. Annual mean iron concentration < 0.01-0.03 mg/L, depending on the water body. Nevada standard: Annual mean total phosphorus concentration \leq 0.05 mg/L.	Maximum concentration of constituent in waters infiltrated into soils: Total nitrogen = 5 mg/L; total phosphate = 1 mg/L; iron = 4 mg/L; turbidity = 200 NTU; grease and oil = 40 mg/L.	mg/L or NTU
Other Lakes	Attain existing water quality standards	Numeric	Attain existing water quality standards	California standards for Fallen Leaf Lake: Mean Total Nitrogen Concentration (May-Oct) < 0.087 mg/L. Annual mean total phosphorus concentration (May-Oct) < 0.008 mg/L. Annual mean iron concentration (May-Oct) < 0.005 mg/L. Annual mean Secchi depth (May-Oct) \geq 18.5 m.	Same as State standards	mg/L; meters (m)

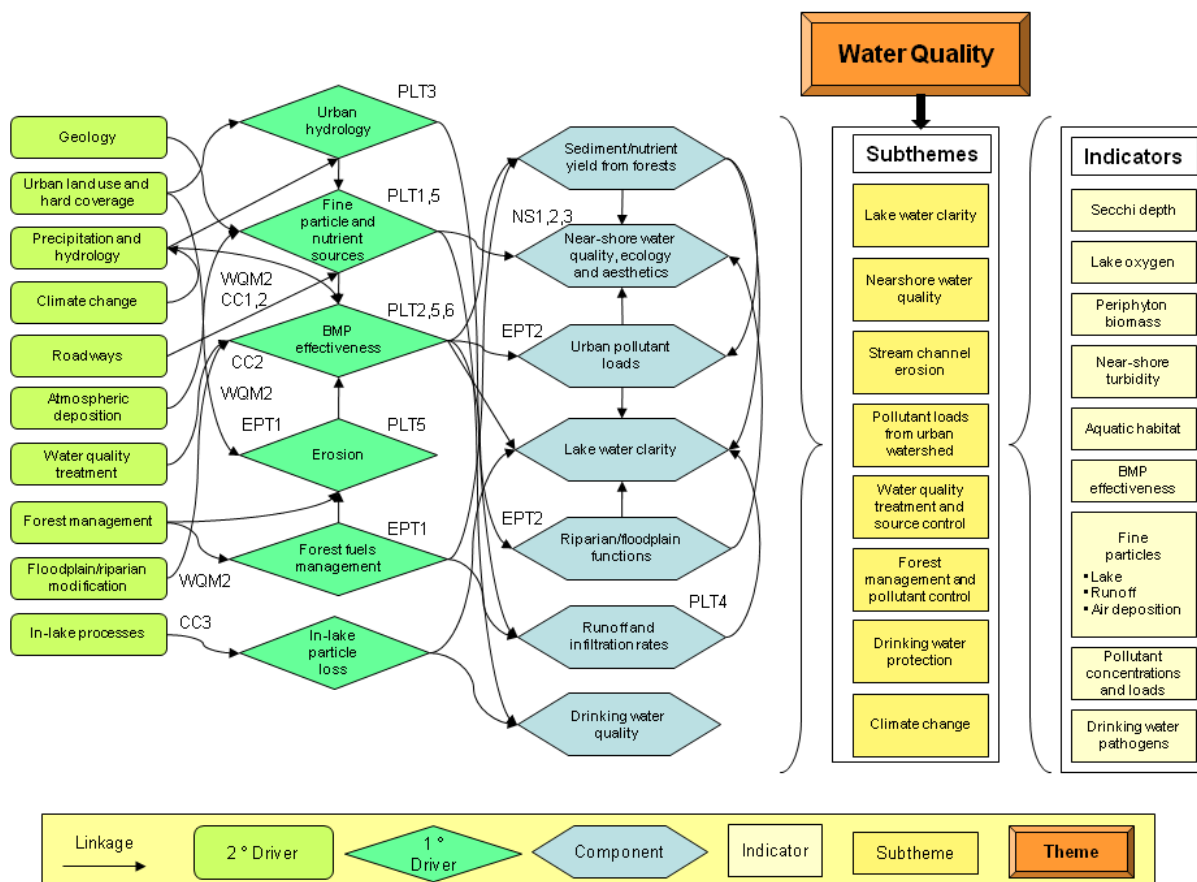


Figure 4-1. Conceptual model for Tahoe Region water quality. This model focuses on the pollutant pathway for fine sediment particles (<16 μm) and nutrients (N and P). Key processes in this pathway include source identification, transport in the watershed, control and abatement, defining loads to Lake, fate in Lake, and assessment of water quality response. For ease of viewing only key linkages were drawn. Source: Hymanson and Collopy 2010.

Lake Tahoe Pelagic Waters

The pelagic zone (offshore, deep waters) is the dominant habitat type or zone of Lake Tahoe. Attaining and maintaining a high level of transparency and exceptional water quality are the basis of Lake Tahoe water quality goals. Both the federal government and California government have designated Lake Tahoe an "Outstanding National Resource Water." The State of Nevada has designated Lake Tahoe a "Water of Extraordinary Ecological or Aesthetic Value." In addition to aesthetic enjoyment, the unique habitats within the Lake, and the exceptional quality of the Lake's water all support a number of beneficial uses related to human and environmental health, including drinking water supply, water contact recreation, wildlife habitat, and aquatic life and habitat.

Two indicators are monitored to document the long-term status and trend of Lake Tahoe's pelagic waters relative to TRPA Numerical Standards: (1) phytoplankton primary productivity, and (2) winter (December – March) average lake transparency. However, annual average lake transparency, a

California standard, is more commonly evaluated and reported, so both Lake transparency indicators are included in this evaluation.

Policy and management strategies to attain Threshold Standards for Tahoe Basin tributary waters are implemented through the *Regional Plan*, and generally aim to reduce pollutant loading to Lake Tahoe. The primary management strategy to improve Lake transparency identified in this Threshold Evaluation focuses on reducing the amount of very fine sediment (i.e., sediment < 16 µm in diameter) entering Lake Tahoe from the watershed and atmosphere. Jassby et al. (1999) forwarded the hypothesis that very fine sediment was substantially affecting Lake transparency in the late 1990s, and research over the last decade has aggressively investigated this hypothesis (see: Swift et al. 2006 and Sahoo et al. 2010). The important influence of very fine sediment particles on Lake transparency has dominated the scientific and management discussion since the mid-2000s, and the Lake Tahoe Total Maximum Daily Load (TMDL) examines the rationale and underlying research for this adopted management strategy in considerable detail. Other important policies and management strategies implemented through the *Regional Plan* to benefit Tahoe Region water quality include:

- Restoring and enhancing stream environment zones (SEZ)
- Limiting the rate and extent of urban growth
- Implementing best management practices (BMPs) on private and commercial properties to reduce nutrient and sediment discharge from disturbed soils
- Reducing private automobile use through improvements to public transit and alternative transportation modes with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment
- Ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects

More specific information about water quality improvement policies and regulations implemented through TRPA permit review processes can be found in the *Regional Plan*. Information about the implementation of environmental improvement projects and water quality mitigation programs is provided in the Implementation and Effectiveness Chapter of this report (Chapter 12).

The status and trends of three Numerical Standards were evaluated to characterize the overall status and trend of the Lake Tahoe pelagic waters Indicator Reporting Category (i.e., pelagic Lake Tahoe). The indicators evaluated included phytoplankton primary productivity, and winter average and annual average Secchi disk depth. The status of these three indicators varied from somewhat better to considerably worse than the target when compared to the interim targets and standards (Figure 4-2). Trends among the three indicators varied between “moderate improvement” (for winter Secchi depth) and “rapid decline” (for phytoplankton primary productivity). The overall trend for the indicator category was characterized as “moderate decline.” Confidence in the determinations of status and trend for the different indicators was “moderate” or “high.” Confidence in the overall status and trend determination for the Lake Tahoe Pelagic Waters Indicator Category was determined to be moderate.

Overall Status and Trend of the Lake Tahoe Pelagic Waters Indicator Reporting Category

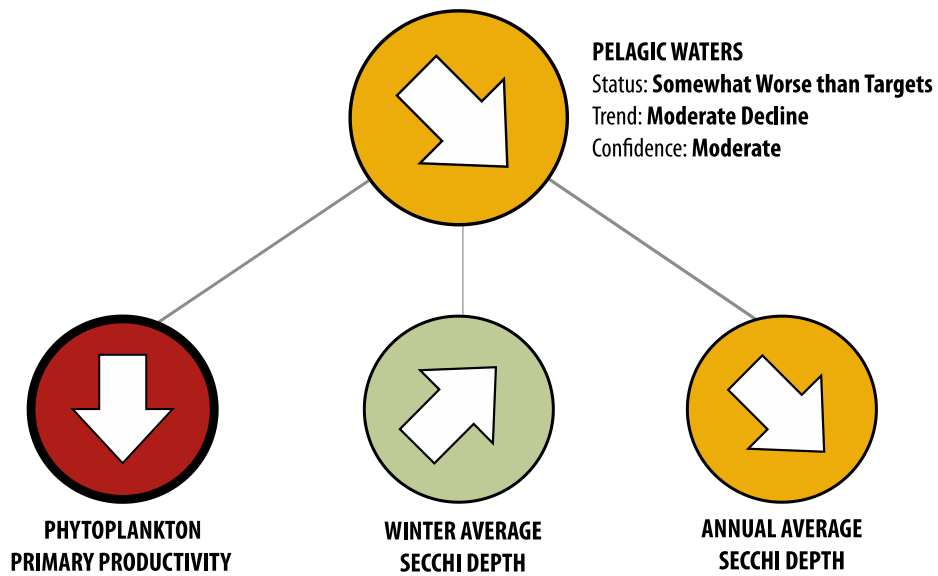
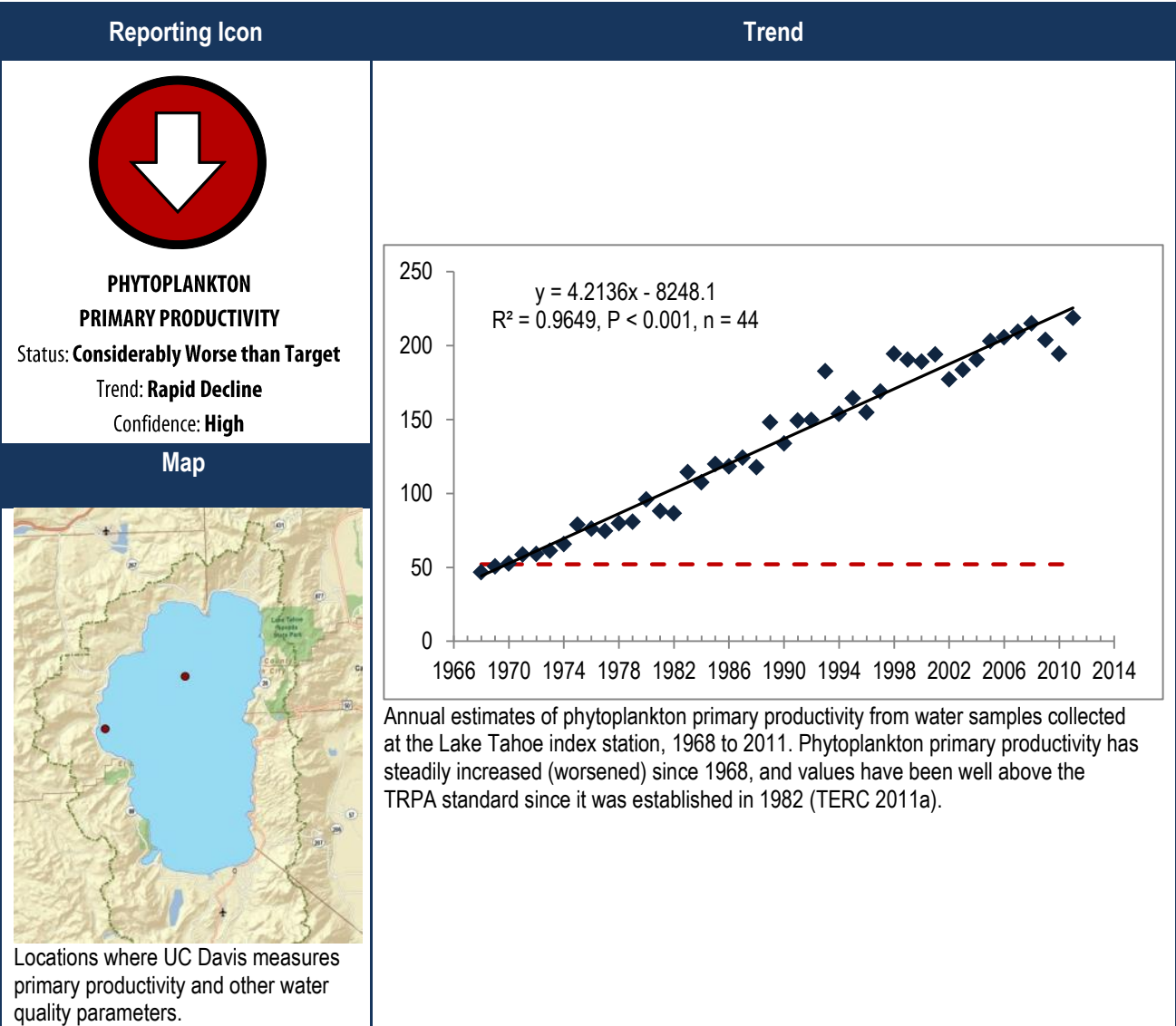


Figure 4-2. Reporting icons for the three indicators evaluated in the Lake Tahoe Pelagic Waters Indicator Reporting Category. Results from each of the three indicators (bottom) were evaluated and aggregated to characterize the overall status of the Lake Tahoe Pelagic Waters Indicator Reporting Category (top).

Pelagic Lake Tahoe: **Phytoplankton Primary Productivity**



Data Evaluation and Interpretation

Relevance – Phytoplankton primary productivity (PPr) is a measure of the rate at which solar energy is converted into chemical energy by photosynthetic phytoplankton organisms (free-floating algae) and is measured in grams of carbon per square meter per year. Free-floating algae (i.e., phytoplankton) occur throughout Lake Tahoe, and contribute to the decline in water transparency by absorbing light for photosynthesis and by scattering light. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). At low levels, algal PPr can become a limiting factor in the population size of organisms that depend directly or indirectly on this source of food. Conversely, extremely high PPr can result in nuisance algal blooms, degradation of drinking water taste and odor, low dissolved oxygen, and fish kills. Because Lake Tahoe is an ultraoligotrophic lake, it is desirable to maintain phytoplankton primary productivity at low levels.

Threshold Category – Water Quality

Indicator Reporting Category – Pelagic Lake Tahoe

Adopted Standards – Achieve the long-term water quality standard of annual mean phytoplankton primary productivity: 52 gC/m²/yr (grams of carbon per square meter per year).

Type of Standard – Numerical

Indicator (Unit of Measure) – Depth-integrated annual average phytoplankton primary productivity expressed as grams Carbon per meter squared per year (gC/m²/yr).

Status – The phytoplankton PPr indicator is used to determine compliance with TRPA's Pelagic Lake Tahoe phytoplankton productivity standard of 52 gC/m²/yr. The Threshold Standard is based on measurements collected over four years (1968-1971) (Lahontan and NDEP 2010). Phytoplankton primary productivity has remained well above the standard since it was established in 1982. In 2010, phytoplankton PPr was 194, and in 2011 phytoplankton PPr was 218.6 gC/m²/yr. The status of Lake Tahoe's phytoplankton primary productivity is considerably worse than the standard because the 2011 value is 4.2 times TRPA's Threshold Standard.

Trend – The line of best fit was determined statistically using a linear regression model. The data show phytoplankton PPr has steadily increased (worsened) since measurements began at Lake Tahoe in 1968 (TERC 2011a). The maximum annual phytoplankton PPr was recorded in 2011 (~218.6 gC/m²/year). The slope of the trendline for the entire period of record (1968-2010) yields an estimated rate of increase in phytoplankton PPr of 4.2 gC/m²/year, which equates to an 8 percent/yr increase in PPr relative to the TRPA Threshold Standard. Thus, this indicator exhibits a rapidly declining trend relative to the adopted standard.

Confidence

Status – There is high confidence in the status determination. Phytoplankton PPr measurements at Lake Tahoe use Standard Operating Procedures and researchers follow an extensive quality assurance and data analysis plan (Winder and Reuter 2009). Researchers have 44 years of data, generated using the same protocols. This is one of the longest continuous records for primary productivity in the world. The most recent value is from 2011. Early studies by UC Davis show that the sampling location is representative of the overall condition of the Lake's deepwater environment (Goldman 1974).

Trend – Confidence in the long-term trend also is "high." The linear regression model explains 96 percent of the variability in annual average phytoplankton PPr values collected over the period of record. The slope of the line is significantly different from zero ($t = 33.99$; $n = 44$; $P < 0.001$).

Overall Confidence – The overall confidence in this indicator is "high" because there is high confidence in both the status and the trend.

Interim Target – Based on the available trend information since 2000, this indicator is predicted to continue to increase (worsen). In 2016, the indicator is projected to be approximately 221 gC/m²/yr.

Target Attainment Date – Based on available trend information it is not possible to accurately estimate a target attainment date. Given the current status and 40-year trend associated with this indicator, it may not be possible to achieve this Threshold Standard within the next 50 years if the trend continues on its same trajectory.

Human and Environmental Drivers – Increasing nutrients (nitrogen and phosphorus) inputs are considered a main cause of increasing PPr in temperate lakes (Conley et al. 2009). It is suspected that activities associated with urbanization and watershed disturbance influence Lake Tahoe's PPr through the generation and subsequent runoff or atmospheric deposition of nutrients. The nutrient source analysis conducted for the Lake Tahoe TMDL indicates that both urban and non-urban sources of nitrogen and phosphorus are important contributors of nutrients to Lake Tahoe (Lahontan and NDEP 2010). Meteorological conditions (e.g., wet vs. dry years) also affect PPr, presumably due to changes in tributary loads of nutrients and differences in the magnitude of physical processes within the Lake. However, the trend analysis suggests these effects have not substantially influenced the overall trend.

Monitoring Approach – Phytoplankton PPr measurements at Lake Tahoe have been made following the same Standard Operating Procedure since the first observations were made in 1967 (Winder and Reuter 2009). Lake water is collected at the UC Davis – Tahoe Environmental Research Center (TERC) West Shore Index station, which was found to be representative of the Lake's deepwater condition (Goldman 1974). Between 1967 and 2006, measurements were taken, on average, every 10-14 days. In 2007, measurement frequency was reduced to once per month due to budget constraints. This reduction in the frequency of measurements was only made after a careful analysis of consequences to the long-term record confirmed that this change in measurement frequency was appropriate. The monthly measurements produced a very similar plot to the bi-monthly data (Winder and Reuter 2009). For each sampling event, water samples are collected from 13 different depths spanning the photic zone (i.e., the vertical zone in the water column exposed to sufficient sunlight for photosynthesis to occur), and analyzed to determine carbon assimilation rates using very sensitive methods needed for pristine or oligotrophic waters (Goldman 1974). Values from the various samples are aggregated to yield a depth-integrated PPr value. These depth-integrated values are aggregated over the calendar year to generate an estimate of average annual phytoplankton PPr.

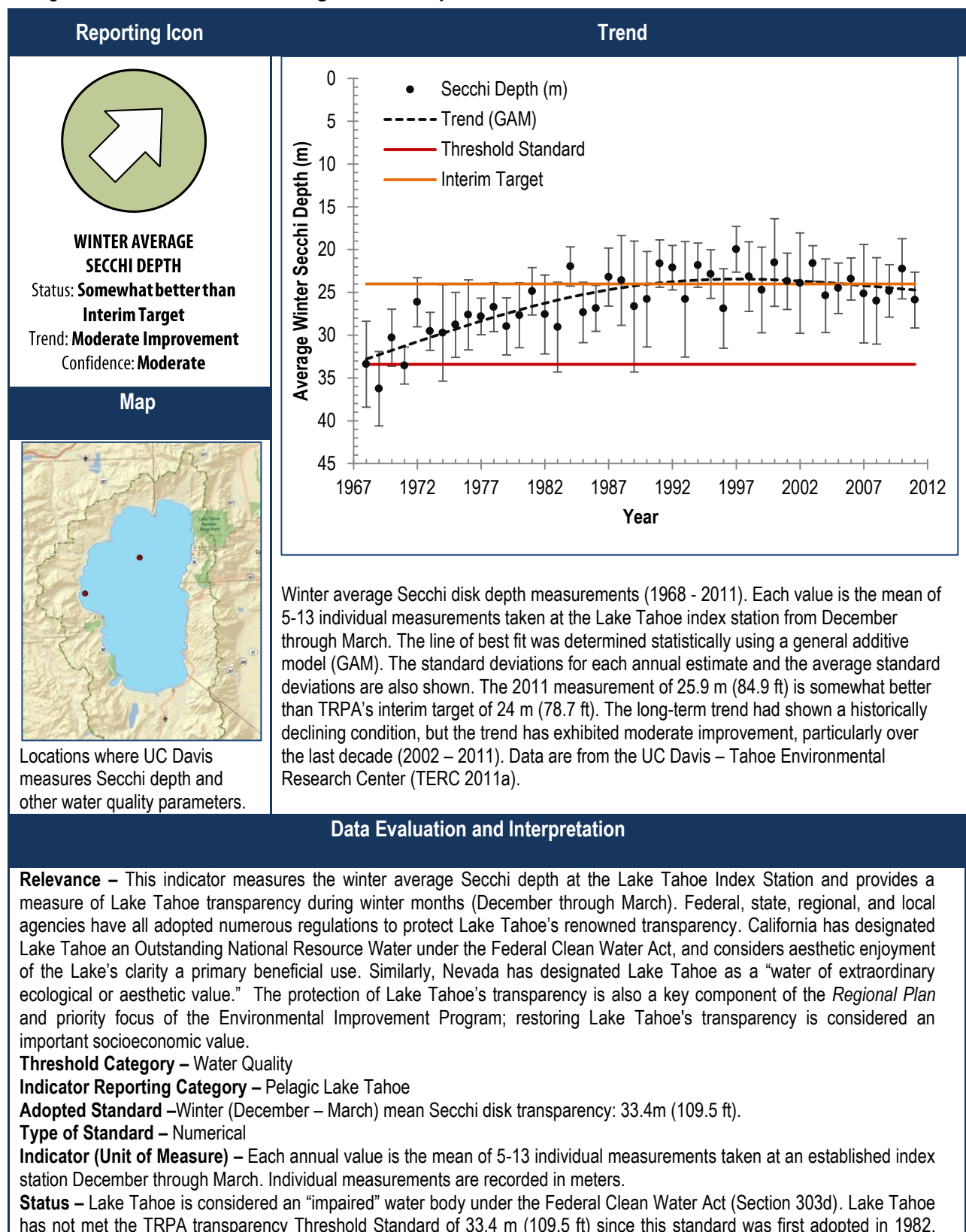
Monitoring Partners – UC Davis–Tahoe Environmental Research Center (TERC), Tahoe Regional Planning Agency, Lahontan Regional Water Quality Control Board.

Programs and Actions Implemented to Improve Conditions – Urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects.

Effectiveness of Programs and Actions – Changes in primary productivity are considered an integrated response to individual actions or programs. As such it is not possible to evaluate the effects of the individual programs or actions. Although each of the programs and actions are thought to aid in improving the transparency of Lake Tahoe, the most current information shows phytoplankton PPr continues to increase at a rate of 8.3 percent/yr relative to the Threshold Standard, suggesting more effective actions are needed.

Recommendations for Additional Actions – TRPA, in collaboration with federal, state, and local agencies, should pursue the strategies and actions identified in the Lake Tahoe TMDL with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Tahoe transparency by 2026. TRPA's near-term implementation role should focus on program areas that it has the existing authority to lead: (1) accelerating implementation of its water quality BMP retrofit regulations including implementation of area-wide stormwater treatment strategies, (2) pursuing innovative redevelopment strategies that aim to accelerate water quality improvements, (3) reducing atmospheric sources of pollutants known to impact aquatic habitats, and (4) considering the phasing out of phosphorus-containing fertilizers in the Region. Additionally and indirectly related to phytoplankton productivity is the need to consider adopting a Threshold Standard for nearshore periphyton (attached) algae. TERC (2011a) reported that periphyton algae have increased in abundance and distribution in recent years.

Pelagic Lake Tahoe: Winter Average Secchi Depth



However, the interim target of 24 m (78.7 ft.) has been met or exceeded numerous times over the period of record, including 2011. The interim target was identified in the 2006 Threshold Evaluation report (TRPA 2007). In 2011, the winter average Secchi depth was 25.9 m (84.9 ft), an improvement of 3.7 m (11 ft) from the 2010 value. However, the reader is cautioned from placing too much importance to this year-over-year change. This amount of change between years is not extraordinary for the winter average Secchi depth. Relative to the interim target, the status of winter lake transparency is “somewhat better than the target,” because the 2011 value is about 8 percent better than the interim target. However, the current indicator value (2011, 25.9m) is “somewhat worse” than the adopted Threshold Standard of 33.4m, measuring 22 percent below the Threshold Standard.

Trend – The line of best fit to describe the long-term trend was determined statistically using a general additive model (GAM). While lake clarity has improved for brief periods since 1968, the overall long-term trend had shown a significant decline. In the last 10 years, however, Secchi depth measurements have been better than predicted by a long-term linear trend. That is, the rate of decline in winter Lake transparency has slowed relative to the trend prior to 2000, and appears as though it may be transitioning to a slight long-term trend of increasing winter transparency (i.e. improving). The overall trend is now better represented by a curve (see figure above), rather than a straight line. This reduction in the rate of decline in Winter Lake Transparency over the last decade is the basis for assigning a trend of moderate improvement.

Confidence –

Status: There is high confidence in the status determination. Secchi depth measurements are used widely as a measure of water transparency in oceans and lakes; it is a highly reliable, relatively simple, and inexpensive measurement of lake transparency. It is among the oldest limnological devices and was first used by Italian Professor P.A. Secchi in the 1860s. Jassby et al. (1999) evaluated the general precision of the method used at Lake Tahoe, and estimated the average precision based on the two observers was ± 0.027 m.

Long Term Trend – Confidence in the long-term trend between 1968 and 2011 is “moderate.” The long-term trend is estimated using a general additive model (GAM), which blends properties of generalized linear models and additive models. The purpose of a GAM is to maximize the quality of prediction of a dependent variable Y from various distributions, by estimating unspecific (non-parametric) functions. The intra-annual variability associated with each average winter estimate is expected as part of the normal ecosystem response due to year-to-year changes in precipitation, runoff, Lake mixing, and meteorology. There is a moderate level of confidence that the trend of improvement in winter average lake transparency observed since about 2000 will continue into the future. Continued monitoring is required to see how this apparent improvement progresses into the future.

Overall Confidence – The overall confidence in this indicator is “moderate” because there is high confidence in the condition status and moderate confidence in the long-term trend.

Interim Target – The interim target established in the 2006 Threshold Evaluation was 78.7 ft. (24 m) (TRPA 2007). Based on the trajectory of the GAM trend, the interim target to be achieved by the next five-year Threshold Evaluation is 25 m (82 ft).

Target Attainment Date – Because of year-to-year variation, estimating a target attainment date is extremely uncertain, especially when estimated attainment dates are projected beyond five years. If actions to control sediment and nutrients from entering Lake Tahoe’s surface waters continue, and the improving trend continues on its current trajectory, it is roughly estimated that the standard would be attained in 25 to 35 years from 2011.

Human and Environmental Drivers – Water transparency in Lake Tahoe is almost exclusively the result of particles blocking light penetration either by scattering or absorption (Swift et al. 2006). Particles in Lake Tahoe are composed of both small, microscopic, free-floating algae (picophytoplankton) and fine sediment that is transported to the Lake with stream and stormwater runoff (Swift et al. 2006), or from atmospheric deposition (Lahontan and NDEP 2010). Excess nutrient (nitrogen and phosphorus) loading, which stimulates algal growth, also contributes to the loss of transparency (Lahontan and NDEP 2010). Drivers influencing the delivery of fine sediment and nutrients include urban development (including the transportation network and vehicle density), anthropogenic and natural disturbance in the undeveloped portions of the watershed, and local and regional climate (especially wind and precipitation).

Monitoring Approach – Transparency measurements are taken in Lake Tahoe using a 25-cm, all white Secchi disk. The disk is lowered into the water column from a boat to a depth at which it is no longer visible by the observer and then raised slowly until visible again. The midpoint of these two depths is called the Secchi depth. Between 5 and 13 individual measurements are taken throughout the winter period (December – March) each year to arrive at an estimate of the winter average Secchi disk depth. The measurements presented in this document are taken from the Index Station, where uninterrupted monitoring has taken place since mid-1967. Although this station appears close to the shoreline, it is >150m deep and is characteristic of open-water. Early studies by UC Davis show that this location is representative of the Lake’s deepwater condition (Goldman 1974).

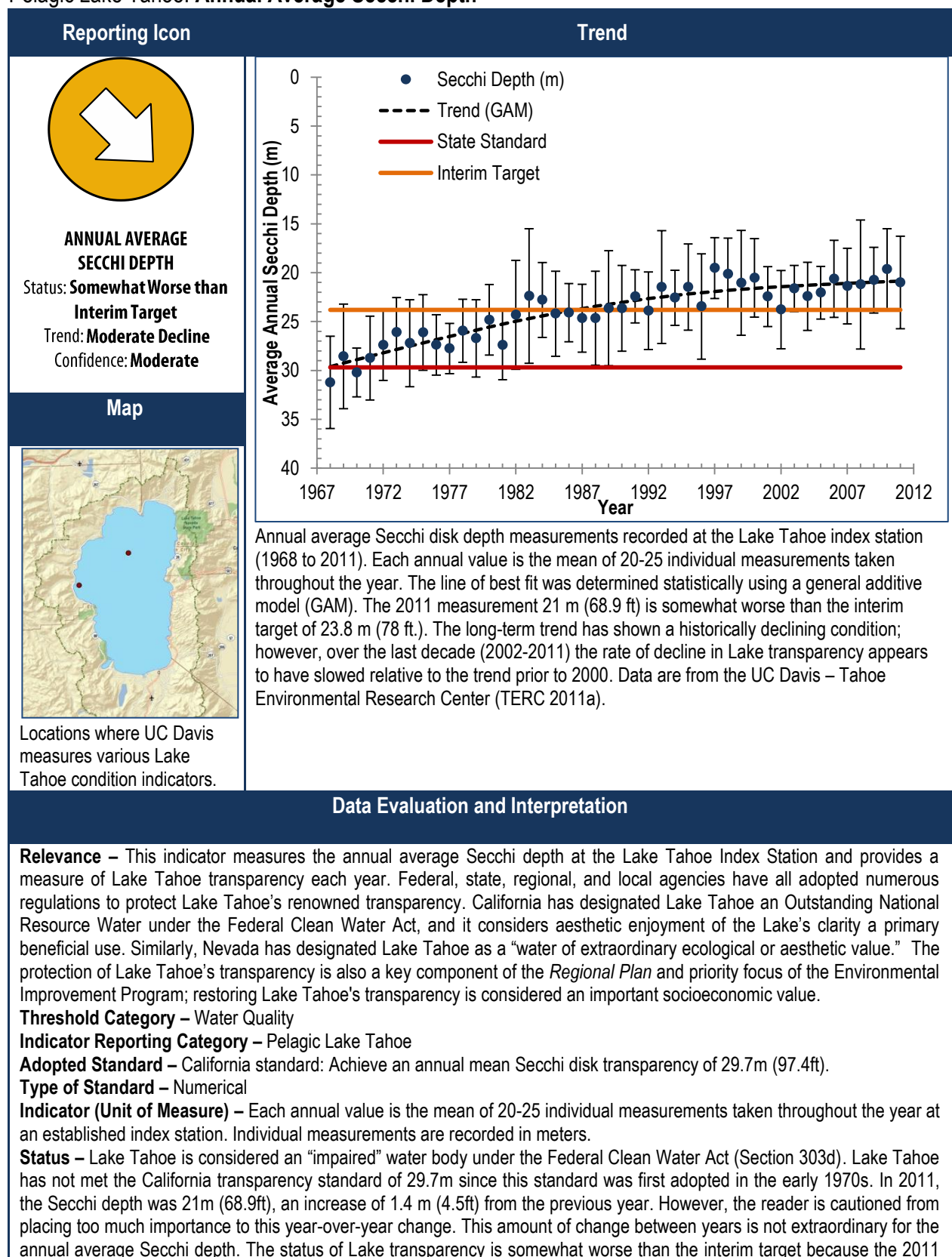
Monitoring Partners – University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency and Lahontan Regional Water Quality Control Board.

Programs and Actions Implemented to Improve Conditions – Urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects.

Effectiveness of Programs and Actions – Changes in Lake transparency are considered an integrated response to individual actions or programs; as such, it is not possible to evaluate the effects of the individual programs or actions. Each of the programs and actions are thought to aid in improving the transparency of Lake Tahoe, and the benefits to transparency are cumulative. The most current information showing a slowing in the rate of decline in winter transparency, and possibly even an improvement, is encouraging.

Recommendations for Additional Actions – TRPA, in collaboration with federal, state, and local agencies, should pursue the strategies and actions identified in the Lake Tahoe TMDL with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim TMDL target for Lake Transparency by 2026. TRPA's near-term implementation role should focus on program areas that it has the existing authority to lead: 1) accelerating implementation of its water quality BMP retrofit regulations, including implementation of area-wide stormwater treatment strategies—especially in areas in closest proximity to Lake Tahoe and other surface waters; 2) pursuing innovative redevelopment strategies that focus project elements on fully treating stormwater runoff and accelerating water quality improvements; 3) reducing atmospheric sources of pollutants known to impact aquatic habitats; and 4) stream zone restoration and enhancement through the EIP, (prioritized to tributary sources with the greatest pollutant load contribution). Actions should include removal and restoration of impervious land cover from these areas to the extent practical.

Pelagic Lake Tahoe: Annual Average Secchi Depth



value is only 12 percent less than the interim target of 23.8m (78 ft.).

Trend – The line of best fit to describe the long-term trend was determined statistically using a general additive model (GAM). While lake transparency has improved during brief periods since 1968, the overall long-term trend had shown a significant decline. In the last ten years, however, Secchi depth measurements have been better than predicted by a long-term linear trend. That is, the rate of decline in Lake transparency appears to have slowed relative to the trend prior to 2000. Statistical analysis supports the observation that the decline in Lake Tahoe's transparency has slowed, and the overall trend is now better represented by a curve (see figure above), rather than a straight line. This reduction in the rate of decline in annual Lake Transparency over the last decade is a direct result of the improvement in the winter average Secchi depth (see evaluation above) and is the basis for assigning a trend of moderate decline. The summer average Secchi depth (not a Threshold Standard) shows a consistent, linear decline since 1967, albeit with considerable inter-annual variability (TERC 2011a).

Confidence –

Status – There is high confidence in the status determination. Secchi depth measurements are used widely as a measure of water transparency in oceans and lakes; it is a highly reliable, relatively simple, and inexpensive measurement of lake transparency. It is among the oldest limnological devices and was first used by Italian Professor P.A. Secchi in the 1860s. Jassby et al. (1999) evaluated the general precision of the method used in Lake Tahoe, and estimated the average precision based on the two observers was ± 0.027 m. A recent analysis of annual average Secchi depth readings (includes water conditions down to a depth of ~20 m in recent years) and the vertical extinction coefficient (a measure of the rate of light attenuation, measured with a sensor down to ~ 100 m), has shown these two measures of light penetration in Lake Tahoe to be well correlated over the entire period of record (TERC 2011b).

Long Term Trend – Confidence in the long-term trend between 1968 and 2011 is “moderate.” The long-term trend is estimated using a general additive model (GAM), which blends properties of generalized linear models and additive models. The purpose of a GAM is to maximize the quality of prediction of a dependent variable from various distributions, by estimating unspecific (non-parametric) functions. The intra-annual variability associated with each average annual estimate is expected as part of the normal ecosystem response due to year-to-year changes in precipitation, runoff, Lake mixing, and meteorology. There is a moderate level of confidence that the trend of improvement in annual average lake transparency observed since about 2000 will continue into the future. Continued monitoring is required to see how this apparent improvement progresses into the future.

Overall Confidence – The overall confidence in this indicator is “moderate” because there is high confidence in the condition status, and moderate confidence in the long-term trend.

Interim Target – An interim target of 23.8m (78 ft.) annual average Secchi disk depth has been established through development of the Lake Tahoe TMDL. This interim target has been adopted by the Lahontan Regional Water Quality Control Board, CA Water Resources Control Board, Nevada Division of Environmental Protection, and the US Environmental Protection Agency. The interim target for the next five-year reporting period should strive to achieve targets identified for the Lake Tahoe TMDL “Clarity Challenge.”

Target Attainment Date – Modeling completed for the TMDL estimates (Lahontan and NDEP 2010) that the adopted annual average Secchi depth standard (29.7 meters, 97.4 feet) would be achieved around 2076 if prescribed management actions are implemented and maintained.

Human and Environmental Drivers – Water transparency in Lake Tahoe is almost exclusively the result of particles blocking light penetration either by scattering or by absorption (Swift et al. 2006). Particles in Lake Tahoe are composed of both small, microscopic, free-floating algae (phytoplankton) and fine sediment that is transported to the lake with stream and stormwater runoff (Swift et al. 2006), or from atmospheric deposition (Lahontan and NDEP 2010). Excess nutrient (nitrogen and phosphorus) loading which stimulates algal growth also contributes to the loss of transparency (Lahontan and NDEP 2010). Drivers influencing the delivery of fine sediment and nutrients include urban development (including the transportation network and vehicle density), anthropogenic and natural disturbance in the undeveloped portions of the watershed, and local and regional climate (especially wind and precipitation).

Monitoring Approach – Transparency measurements are taken in Lake Tahoe using a 25-cm, all white Secchi disk. The disk is lowered into the water column from a boat to a depth at which it is no longer visible by the observer, and then raised slowly until visible again. The midpoint of these two depths is called the Secchi depth. Between 20 and 25 individual measurements are taken throughout each year to arrive at an estimate of the annual average Secchi disk depth. The measurements presented in this document are taken from the Index Station, where monitoring has occurred uninterrupted since mid-1967. Although this station appears close to the shoreline, it is >150m deep and is characteristic of open-water. Early studies by UC Davis show that this location is representative of the Lake's deepwater condition (Goldman 1974).

Monitoring Partners – University of California at Davis (Tahoe Environmental Research Center) and Tahoe Regional Planning Agency.

Programs and Actions Implemented to Improve Conditions – Urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects.

Effectiveness of Programs and Actions – Changes in Lake transparency are considered an integrated response to individual actions or programs; as such, it is not possible to evaluate the effects of the individual programs or actions. Each of the programs and actions are thought to aid in improving the transparency of Lake Tahoe, and the benefits to transparency are cumulative. The most current information showing a slowing in the rate of decline in average annual transparency is encouraging, although this is driven by the trend in winter transparency.

Recommendations for Additional Actions – TRPA, in collaboration with federal, state, and local agencies, should pursue the strategies and actions identified in the Lake Tahoe TMDL with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim TMDL target for Lake Transparency by 2026. TRPA's near-term implementation role should focus on program areas that it has the existing authority to lead: 1) accelerating implementation of its water quality BMP retrofit regulations, including implementation of area-wide stormwater treatment strategies—especially in areas in closest proximity to Lake Tahoe and other surface waters; 2) pursuing innovative redevelopment strategies that aim to focus project elements on fully treating stormwater runoff and accelerating water quality improvements; 3) reducing atmospheric sources of pollutants known to impact aquatic habitats, and 4) stream zone restoration and enhancement through the EIP, prioritized to tributary sources with the greatest pollutant load contribution (actions should include the removal and restoration of impervious lands cover from these areas to the extent practical).

Tributary Water Quality

The Tahoe Basin contains 63 streams that flow into Lake Tahoe. These streams drain a total land area of approximately 800 km². Approximately 83 km² or 10.5 percent of the land area, is within “development” context (areas directly and indirectly influenced by urbanization), and much of the development is concentrated near the Lakeshore. Total tributary inflow to Lake Tahoe is approximately 430 million m³ in an average water year (October 1 – September 30) (Hymanson 2009). The Lake Tahoe Interagency Monitoring Program (LTIMP) routinely monitored ten streams through 2010 to track water quality conditions, and continuously monitored for inflow. Together, these ten streams deliver about 50 percent of the total tributary inflow to Lake Tahoe (Lahontan and NDEP 2010). Five of the routinely monitored streams are in Nevada: Third, Incline, Glenbrook, Logan House, and Edgewood creeks; and five of the streams are in California: Trout, General, Blackwood and Ward creeks, and the Upper Truckee River. Of these ten monitored streams, approximately 90 percent of the cumulative total inflow is from the five California streams, and approximately 10 percent is from the five Nevada streams.

Indicators associated with two standards are monitored to document the long-term status and trend of Tahoe Basin tributary waters: (1) attainment of applicable state water quality standards; and (2) total annual loads of nutrients (nitrogen and phosphorus) and suspended sediment (Table 4-1). Attainment of applicable state standards relies on the measured concentrations of nutrients and suspended sediments to evaluate status and trends relative to established state numerical standards (i.e., targets). Although quantitative information on total yearly loads of nutrients and suspended sediment is available through the Lake Tahoe Interagency Monitoring Program (and presented in this section), comparison with TRPA's Management Standards was problematic because 1) data presented in TRPA (1982b; the source of the adopted standard) were limited to a few tributaries, or otherwise roughly estimated, leading to uncertainty on what the load target is, and 2) prescribed Management Standard pollutant loading levels do not represent the loads that contributed to the desired transparency level identified by adopted standards for pelagic and littoral Lake Tahoe. Thus, achieving the prescribed Management Standard load may not lead to conditions sought for pelagic and littoral Lake Tahoe.

Inter-annual variability in local weather and the resulting amounts, timing, and type of precipitation have a strong influence on stream inflow and the resulting loads of sediments and nutrients (Coats et al 2008, Gunter, 2005). The influence of natural stream inflow on annual pollutant loads is readily apparent in the data presented in this section. Flow-weighted concentrations of sediment, nitrogen, and phosphorus were examined to reveal the underlying trends in pollutant concentrations. Although there are no established standards for flow-weighted concentrations of pollutants, an examination of their trends is thought to provide more insight into the influence of TRPA policies and management actions.

Policy and management actions to attain standards for Tahoe Basin tributary waters are implemented through the *Regional Plan* and Environmental Improvement Program, and generally aim to reduce pollutant loading to Lake Tahoe. These actions include:

- Restoring and enhancing stream environment zones (SEZ)
- Limiting the rate and extent of urban growth
- Implementing best management practices (BMPs) on private and commercial properties to reduce nutrient and sediment discharge from disturbed soils

- Reducing private automobile use through improvements to public transit and alternative transportation modes with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment
- Ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects

More specific information about these actions is provided in *Chapter 12: Implementation and Effectiveness*.

The status and trends of six indicators were evaluated for the tributary Water Quality Indicator Reporting Category. Data for the indicators were derived from 10 monitoring sites located at the mouth of 10 different streams. Evaluated indicators included concentrations of suspended sediment, total phosphorus and total nitrogen, and combined tributary loads of sediment, phosphorus, and nitrogen. Overall, the status of these three indicators ranged from “considerably worse than target” to “considerably better than target,” and the trend varied between “little or no change” (total nitrogen concentration) and “rapid improvement” (nitrate and nitrite load) (Figure 4-3). Confidence in the determinations of status and trend are all “moderate” resulting primarily from “high” confidence in the status determination, and “low” confidence in the trend determinations. Overall, the status for the tributary Water Quality Indicator Reporting Category was “somewhat worse than the target,” with an overall trend of “moderate improvement” (Figure 4-3).

Overall Status and Trend of the Tributary Water Quality Indicator Reporting Category

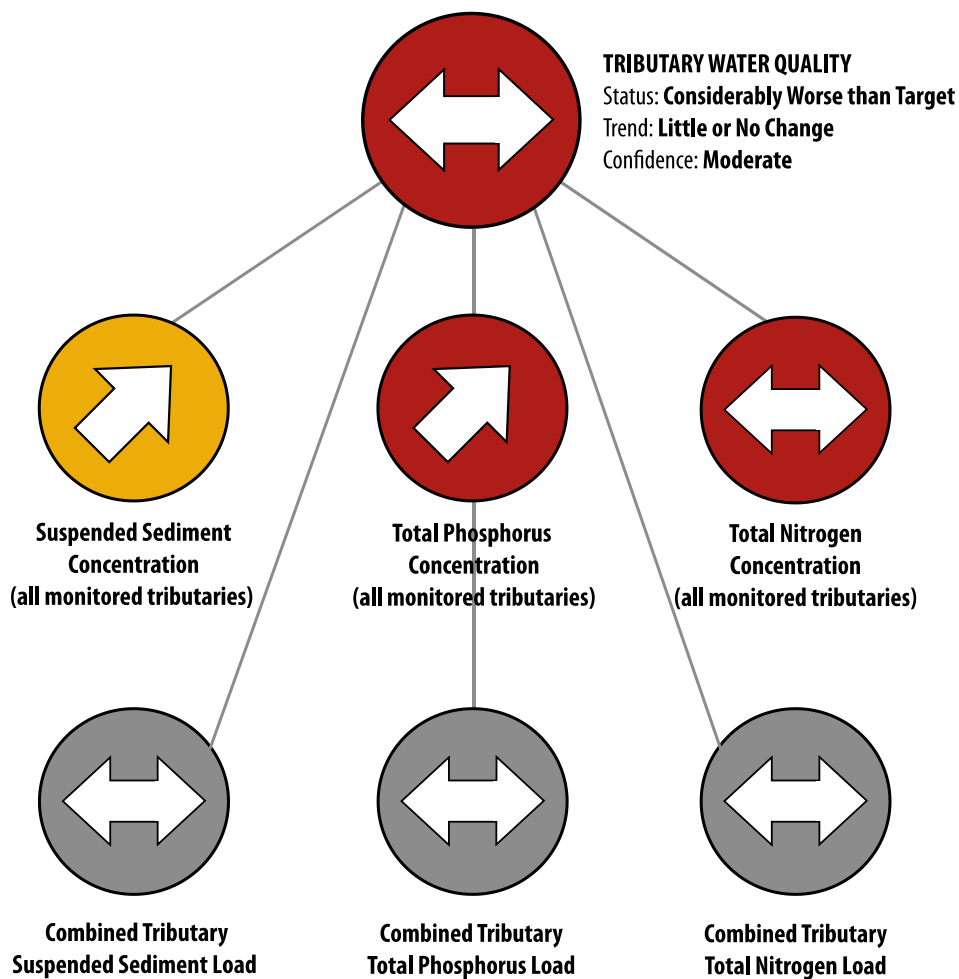
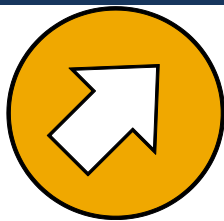


Figure 4-3. Reporting icons for the six indicators evaluated in the Tributary Indicator Reporting Category. Results from each of the six indicators (bottom) were evaluated and aggregated to characterize the overall status of the Tributary Indicator Reporting Category (top).

Tributaries: Suspended Sediment Concentration

Reporting Icon



Suspended Sediment Concentration

Status: **Somewhat Worse Than Target**

Trend: **Moderate Improvement**

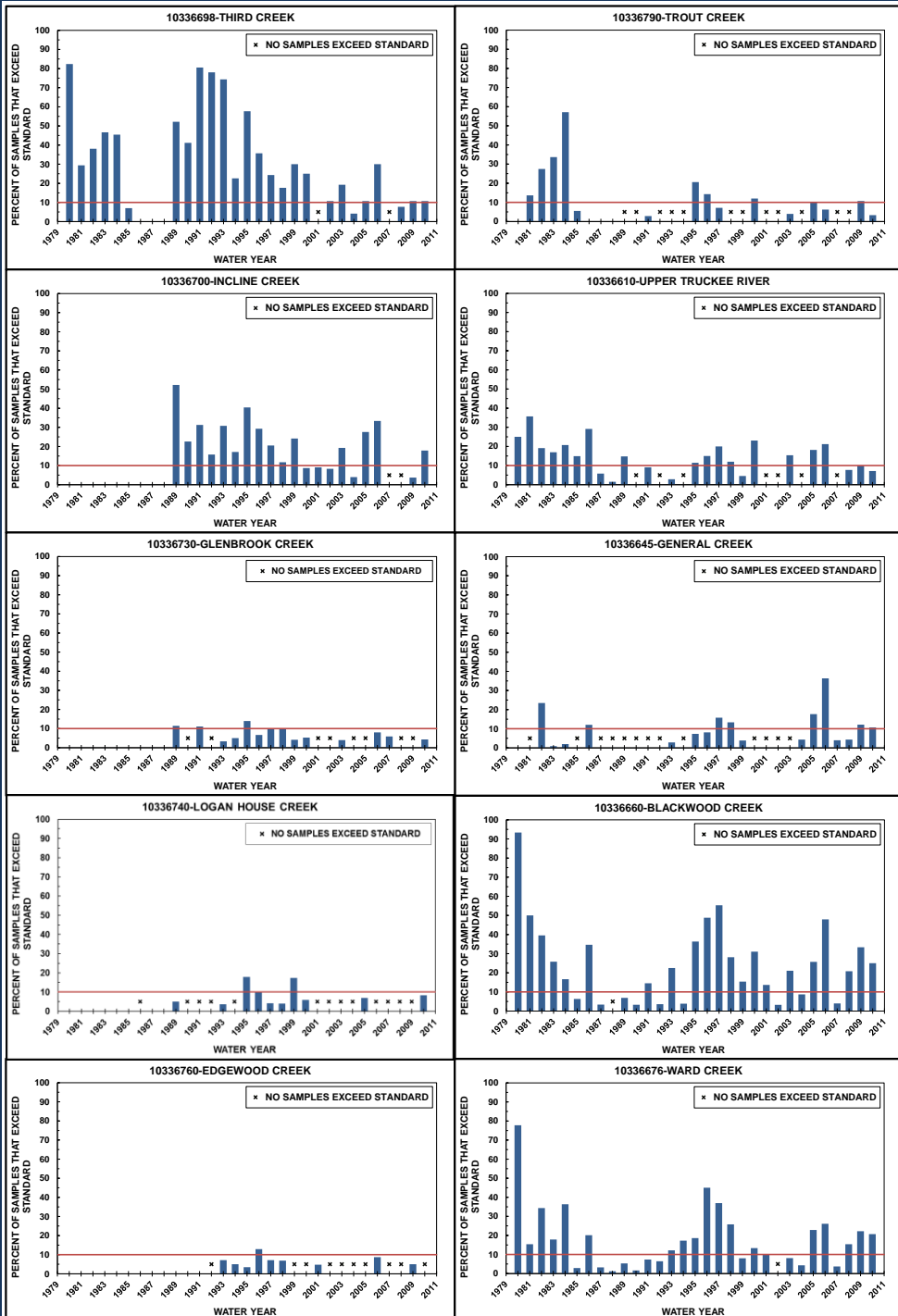
Confidence: **Moderate**

Map



The ten streams routinely monitored for suspended sediment include five streams in Nevada and five streams in California: Ninety percent of the cumulative total inflow from the monitored streams is from the five California streams, and ten percent is from the five Nevada streams. The sub-watersheds where stream monitoring occurs are colored in the figure above.

Trend



These plots show measurements of suspended sediment (SS) concentration compared to the water quality standard in place for each of ten regularly monitored Lake Tahoe tributaries by water year. The individual bars presented for each water year (Oct. 1 - Sept. 30) represent the proportion of all individual samples collected in a water year that exceeded 60 milligrams per liter (mg/L). A total of 2-157 individual samples were collected, depending on the water year,

from each of the 10 monitored streams. The SS standard for both California and Tahoe Regional Planning Agency (TRPA) states that the stream must attain a 90th percentile value for suspended sediment concentration of 60 mg/L. This is interpreted as no more than ten percent of the stream's SS concentration measurements for the water year can exceed 60 mg/L. The horizontal red line represents this standard. The symbol 'x' denotes that sufficient samples were collected and that none of the samples contained SS concentrations greater than 60 mg/L. Years without data or an 'x' means that no samples were collected, or that data is otherwise missing. Stream monitoring data used to evaluate SS concentrations are from the sampling locations closest to where the tributaries discharge to Lake Tahoe. Data are from the Lake Tahoe Interagency Monitoring Program (LTIMP).

Data Evaluation and Interpretation

Relevance – Sediment (particularly fine sediment) delivered to Lake Tahoe is known to directly affect the transparency of Lake Tahoe (Lahontan and NDEP 2010). The protection and restoration of the Lake's transparency is a central environmental goal, and Lake transparency is considered a key socioeconomic value. Under the Federal Clean Water Act, and in California under the Porter-Cologne Act, each state develops a set of water quality standards designed to protect the beneficial uses of a waterbody. These standards can be narrative, numeric or both. For California streams in the Lake Tahoe Basin, the standard states that suspended sediment (SS) concentrations in tributaries to Lake Tahoe shall not exceed a 90th percentile value of 60 mg/L (Lahontan 1995). TRPA also has authority to establish standards, and it adopted an equivalent Numerical Standard in Resolution 82-11 (TRPA 1986). Nevada does not have a Numerical Standard for SS, however the TRPA Threshold Standard applies to streams on the Nevada side of the Lake Tahoe Basin. In the Basin, Lahontan Regional Water Quality Control Board (CA), Nevada Division of Environmental Protection (NV), and TRPA have the individual authority to determine if standards have been violated.

Threshold Category – Water Quality

Indicator Category – Tributaries

Adopted Standard – Attain a 90th percentile value for suspended sediment concentration of 60 mg/L (milligrams per liter).

Type of Standard – Numerical.

Indicator (Unit of Measure) – The Indicator is suspended sediment concentration (expressed as milligrams per liter; mg/L), but the unit of measure reported here is the proportion of suspended sediment samples that exceeded 60 mg/L each water year (Oct. 1 – Sept. 30). Currently a total of 20-35 individual suspended sediment samples are collected each water year from each of the ten regularly monitored streams. However, the number of individual samples collected each water year has varied over the period of record from 2 to 157. For example, if a total of 30 individual samples were collected from a stream in a given water year, 27 samples (90 percent) would need to have a SS concentration ≤60 mg/L to meet the standard. Conversely, only 3 samples (10 percent) could have a SS concentration > 60 mg/L.

Status – In the table below, scores of suspended sediment concentration status, trend, and confidence were assigned for each of the ten regularly monitored streams in the Lake Tahoe Basin. Assigned scores for individual streams for California and Nevada, and overall, were based on: 1) percent to target calculations, 2) standard exceedance rates (see also Appendix WQ-1), 3) visual inspection of graphed data, and 4) the aggregation methods described in the Methodology Chapter of this report. The status for each stream was determined by evaluation of its 2010 value relative to the standard. The trend determination was based on a comparison of the exceedance rate among three periods, 1980-1989, 1990-1999, and 2000-2010. More details on confidence scoring are provided in the confidence section below. Five of the ten monitored streams in water year 2010 exceeded the standard for suspended sediment concentration (see table below and figure above in this indicator summary). The percentage of samples for each stream that exceeded the standard ranged from 11 to 25 percent. Two of the streams were in Nevada (Third and Incline creeks), and three of the streams were in California (General, Blackwood, and Ward Creeks). Ninety percent of all inflow delivered to Lake Tahoe from the ten monitored streams comes from the five California streams; thus, the total contribution of SS from California streams was substantially larger than from the Nevada streams. Due to the relatively larger influence of California streams, the status of tributary SS concentration was determined to be “somewhat worse than the target,” even though the overall average would indicate that the Region was “at or somewhat better than the target.”

Stream	Status	Trend	Confidence
Nevada Streams			
Third	-2	4	0
Incline	-2	4	0
Glenbrook	2	2	0
Logan House	2	2	0
Edgewood	2	2	0
Nevada Summary	0.4	1.2	0
California Streams			
Trout	2	2	0
Upper Truckee	2	2	0
General	-2	0	0
Blackwood	-2	0	0
Ward	-2	2	0
California Summary	-0.4	1.6	0
Overall Summary	0.0	1.4	0
Overall Qualitative Assessment	At or Somewhat Better than Target	Moderate Improvement	Moderate

Trends – Aggregation of the individual trends in SS concentrations relative to the standard for the ten individual streams suggest there is “moderate improvement” in overall trend (see table above). The ten monitored streams can be divided into three categories in terms of trend analysis: 1) SS standard infrequently exceeded, and minimally so, 2) SS standard frequently exceeded, but minimally so, and 3) SS standard frequently exceeded by a substantial amount. Streams in the first category include General, Glenbrook, Logan House and Edgewood creeks. With the exception of General Creek, streams in the first category (SS standards infrequently exceeded, and minimally so) have not exceeded the SS concentration standard in any year over the last decade; thus, the streams in this category are determined to exhibit no trend in SS concentration relative to the established Threshold Standard.

Trout Creek and the Upper Truckee River are examples of streams meeting criteria for the second category: frequently exceeded the standard, but minimally so. During the early to mid-1980s, the proportion of samples per year that was greater than 60 mg/L averaged 20 to 25 percent when the standard was exceeded. For both Trout Creek and the Upper Truckee River, the standard was exceeded more frequently, and by a greater percentage (above the 60 mg/L value) than in the last two decades (1990 – 2010). Since the early 1990s Trout Creek has rarely exceeded the SS standard. Upper Truckee has also seen a reduction in percent of samples with SS concentrations above 60 mg/L. Thus, a trend of moderately improving SS concentration is assigned to these tributaries.

Streams falling into category number three (i.e., standard frequently exceeded by a large amount) include Ward, Blackwood, Third and Incline creeks. Third and Incline creeks differed from the others in this category in that the number of years SS concentrations exceeded the standard have declined since the early 2000s. A snow avalanche that occurred in the Third Creek watershed in 1986 may explain the increased SS concentrations measured in the late 1980s and early 1990s. In contrast, the routing of Rosewood Creek, a tributary to Third Creek changed in the early 2000s, and Rosewood Creek now enters Third Creek downstream of the established sampling station. This may explain (at least in part) the reduction in yearly average SS concentrations measured in Third Creek over the last decade, and its assignment of a moderately improving trend. The percentage of samples from Blackwood and Ward creeks that are greater than 60 mg/L track each other fairly well, and these watersheds are located next to each other on the West Shore of Lake Tahoe. These watersheds are relatively undeveloped (although Blackwood has historically been highly disturbed), are dominated by more erosive volcanic soils, and receive relatively higher amounts of precipitation compared to the East Shore. It is hypothesized that the higher SS concentrations measured in these streams are driven by local meteorology and runoff characteristics. This is further supported by comparing inflow in combination with estimates of SS loads for Blackwood and Ward creeks (streams with similar flow characteristics). Overall, localized conditions and events are thought to have a strong influence on SS concentrations in the four streams falling into the third category, obscuring any definitive long-term trends.

Confidence –

Status – There is high confidence in the reliability of the SS concentration data as the data collection consistently followed

national field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). All data, field and laboratory, are subject to extensive quality assurance requirements (USGS 2006). Currently, a total of 20-35 individual samples are collected each water year from each of the ten regularly monitored streams. This sampling frequency is considered sufficient to characterize different inflow conditions observed during the water year; however, the sampling frequency has varied over the period of record. The stream monitoring program focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). The analytical methods for measuring sediment, fine particles and nutrients have been developed and customized for use in aquatic systems where concentrations can be extremely low (Goldman et al. 2009). Thus, there is high confidence in the status determination.

Trend – Confidence in the trend determinations are all considered “low.” Although there is high confidence in the data, assessments and interpretations of trend are all based on visual inspection of the graphical information (i.e., qualitative).

Overall Confidence – Overall confidence in the status and trend determination is “moderate” given the high confidence in status and the low confidence in trend.

Interim Target – Based on visual inspection of the data record, seven of ten monitored streams should be in compliance with the SS concentration standard by the next major evaluation (it is suspected that Blackwood, Ward, and Incline Creeks will remain out of attainment with adopted Threshold Standards).

Target Attainment Date – Provided that actions to reduce suspended sediment delivery to surface waters are implemented at a sustained pace and trends in SS concentrations continue to decline, it is roughly estimated that the Region should attain this standard by about 2031. However, there is no way to assign confidence to this attainment date estimate as it was qualitatively assigned.

Human and Environmental Drivers – Within the Tahoe Basin, all the tributaries deliver sediment and nutrients to a single downstream water body, Lake Tahoe. Lake Tahoe has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the Lake from west to east, where precipitation can be twice as high on the West Shore relative to the East Shore. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain nutrients. Landscape disturbances including, but not exclusive to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the Lake or its tributaries. Weather variations and long-term climate change are considered among the most important environmental drivers of tributary runoff.

Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to provide a Basin-wide evaluation of sediment and nutrient input from tributaries to Lake Tahoe, and to support research efforts that aim to understand the drivers affecting the transparency of Lake Tahoe. Ten streams have been monitored since the early 1990s; five in California (Upper Truckee River, and Trout, General, Blackwood, and Ward creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood creeks). Six of these streams have been monitored since water years 1980 or 1981. Some of the ten streams have had multiple monitoring stations along the tributary and all have primary monitoring stations at or near the point of stream discharge to Lake Tahoe. Currently a total of 20-35 individual samples are collected each water year from each of the monitoring stations. The ten primary stations allow for the evaluation of the cumulative conditions within the watershed and represent approximately 50 percent of the yearly tributary inflow into Lake Tahoe (Lahontan and NDEP 2010). U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Other water quality-related constituents monitored include water and air temperature, pH, specific conductance, and dissolved oxygen.

Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, and U.S. Forest Service – Lake Tahoe Basin Management Unit

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property water quality BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects

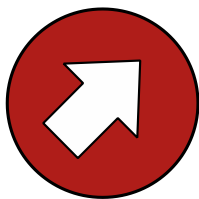
Effectiveness of Programs and Actions – Insufficient data exists to quantitatively evaluate the effectiveness of any individual program or action implemented to improve the quality of Lake Tahoe Basin tributary waters. High inter-annual variability in concentrations of suspended sediment, which is thought to be primarily driven by variability in annual precipitation, complicates the determination of overall effectiveness of the *Regional Plan* and actions taken by Regional partners. Based on visual

inspection of the overall long-term trend, it appears that compliance measures adopted in the *Regional Plan* and actions taken by Regional partners have at least maintained water quality, because tributary suspended sediment concentrations show no signs of increase.

Recommendations for Additional Actions – TRPA, in collaboration with federal, state, and local agencies, should pursue the strategies and actions identified in the Lake Tahoe TMDL with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for annual average Lake Transparency by 2026. TRPA's near-term implementation role should focus on program areas that it has the existing authority to lead: 1) accelerating implementation of its water quality BMP retrofit regulations including implementation of area-wide stormwater treatment strategies, 2) pursuing innovative redevelopment strategies that aim to accelerate water quality improvements, 3) reducing atmospheric sources of pollutants known to impact aquatic habitats, (4) SEZ restoration and enhancement through the EIP (prioritized to tributary sources with the greatest pollutant load contribution), and 5) continued support for long-term stream monitoring.

Tributaries: Total Phosphorus Concentration

Reporting Icon



TOTAL PHOSPHORUS CONCENTRATION

Status: **Considerably Worse than Target**

Trend: **Moderate Improvement**

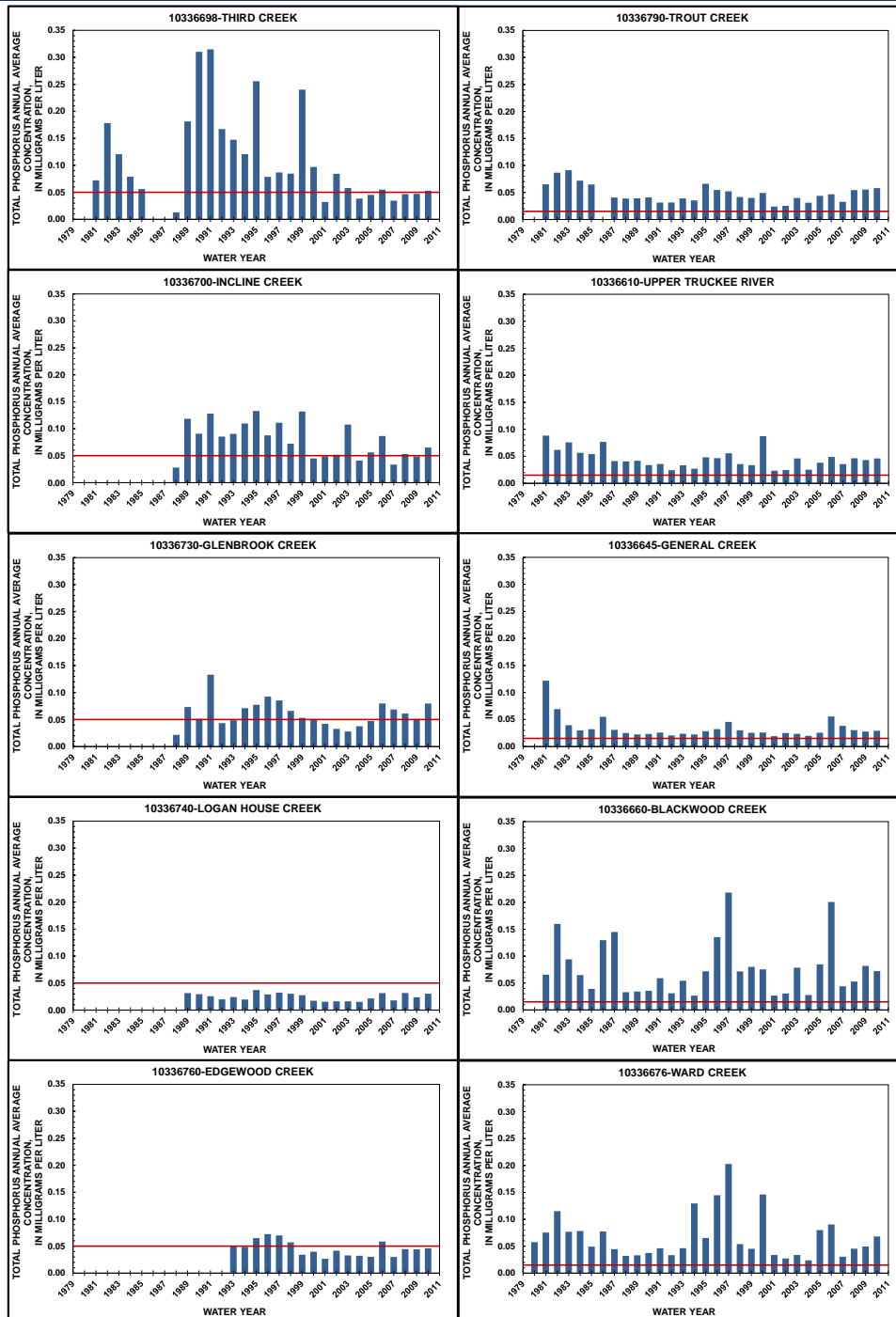
Confidence: **Moderate**

Map



The ten streams routinely monitored for total phosphorus concentrations include five streams in Nevada and five streams in California: Ninety percent of the cumulative total inflow from the ten monitored streams is from the five California streams, and ten percent is from the five Nevada streams. The sub-watersheds where stream monitoring occurs are colored in the figure above.

Trend



These plots show how average yearly total phosphorus (TP) concentration, determined from samples collected during a water year (Oct. 1-Sept. 30), compare to the water quality standard in place for each of ten regularly monitored streams in the Lake Tahoe Basin. The individual bars represent the average TP concentration, based on a total of 3-138 individual samples

collected, depending on the water year from each of the ten monitored streams. The horizontal red line represents the Numeric Standard of 0.05 milligrams per liter (mg/L) for streams in Nevada (graphs on left side, above), and the Numeric Standard of 0.015 mg/L for streams in California (graphs on right side, above). Stream monitoring data used to evaluate TP concentrations are from the sampling locations closest to where the tributaries discharge to Lake Tahoe. Data are from the Lake Tahoe Interagency Monitoring Program (LTIMP).

Data Evaluation and Interpretation

Relevance – Phosphorus is a nutrient important to the growth and reproduction of plants, and it is considered a pollutant of concern in the Lake Tahoe Basin (Lahontan 1995). Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (TERC 2011a). Free-floating algae (i.e., phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis and scattering light. Attached algae (i.e., periphyton) coat rocks in the near shore, adversely impacting near shore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). Under the Federal Clean Water Act, and in California under the Porter-Cologne Act, each State develops a set of water quality standards designed to protect the beneficial uses of a waterbody. In the Tahoe Basin, Lahontan Regional Water Quality Control Board (CA), Nevada Division of Environmental Protection (NV), and TRPA have the individual authority to determine if standards have been violated.

Threshold Category – Water Quality

Indicator Category – Tributaries

Adopted Standard – TRPA: Attain applicable State standards for concentrations of dissolved phosphorus; Nevada: The yearly average TP concentration cannot exceed 0.05 mg/L in all tributaries to Lake Tahoe located in Nevada (NAC [no date]); California: The yearly average concentration cannot exceed 0.015 mg/L in the Upper Truckee River, and Trout, General, Blackwood, and Ward creeks (Lahontan 1995).

Type of Standard – Numerical

Indicator (Unit of Measure) – The Indicator is average yearly total phosphorus (TP) concentration measured over a water year (Oct. 1-Sept. 30). Average TP concentration is based on a total of 20-35 individual samples currently collected each water year from each of the ten monitored streams, although the number of individual samples collected each water year has varied during the period of record from three to 138. The average yearly TP concentration values presented here differ from the flow-weighted concentrations in that the former value is the straight arithmetic mean of the measured values within a given water year, regardless of inflow. All average TP concentrations are reported in milligrams per liter (mg/L).

Status: In the table below, scores for annual average TP concentration status, trend, and confidence were assigned for each of the ten regularly monitored streams in the Lake Tahoe Basin. Assigned scores for individual streams for California and Nevada and overall, are based on: 1) percent to target calculations, 2) standard exceedance rate (see also Appendix WQ-1), 3) visual inspection of graphed data record, and 4) the aggregation methods described in the Methodology Chapter of this report.

The annual average TP concentrations for water year 2010 for the five Nevada streams ranged from 0.030 mg/L (Logan House Creek; 40 percent of standard) to 0.080 mg/L (Glenbrook Creek, 60 percent greater than the standard); and from 0.029 mg/L (General Creek, 93 percent greater than the standard) to 0.072 mg/L (Blackwood Creek, 480 percent greater than the standard) for the five California streams. Ninety percent of all inflow delivered to Lake Tahoe from the ten monitored streams comes from the five California streams; thus, the total contribution of TP from California streams was substantially greater than from the Nevada streams. Overall, the current status of tributary TP concentration was determined to be “considerably worse than target.”

Stream	Status	Trend	Confidence
Nevada Streams			
Third	-2	4	0
Incline	-4	4	0
Glenbrook	-4	4	0
Logan House	4	0	0
Edgewood	2	4	0
Nevada Summary	-0.8	3.2	0
California Streams			
Trout	-4	0	0
Upper Truckee	-4	0	0
General	-4	0	0
Blackwood	-4	0	0
Ward	-4	0	0
California Summary	-4	0	0
Overall Average	-2.4	1.6	0
Overall Qualitative Assessment	Considerably Worse Than Target	Moderate Improvement	Moderate

Trend – Overall, it was determined the trend in TP concentration exhibited “moderate improvement” based on the change in standard exceedance rate between the 1990-1999 and the 2000-2010 periods (i.e., fewer exceedances of adopted standards were observed in the most recent period). Between water years 1981 and 2010, the average TP concentrations for the five Nevada streams ranged from 0.013 mg/L (26 percent of the standard) to 0.315 mg/L (630 percent greater than the standard). The yearly average TP concentrations for the five California streams ranged from 0.019 mg/L (27 percent greater than the standard) to 0.218 mg/L (1,453 percent greater than the standard) over the same period (see also Appendix WQ-1). At no time during the monitoring record have California streams attained the TP concentration standard.

Patterns and trends in the streams from each State are evaluated separately, since the TP numeric standard for Nevada (0.05 mg/L) is 3.3 times larger than the California standard (0.015 mg/L). In Nevada, average TP concentrations in Logan House Creek were below the 0.05 mg/L standard, and in Edgewood Creek were near (within 0.02 mg/L) or below the 0.05 mg/L standard. Annual average Glenbrook Creek TP concentrations were at or above the standard more frequently than Edgewood, but the yearly average concentrations hovered close to 0.05 mg/L. The time series for these three streams exhibit low but relatively stable annual average TP concentrations over the period of record. Annual average TP concentrations in Incline Creek and Third Creek frequently exceeded the standard during the period 1989-1999. However, the number of exceedances has declined since 2001. The annual average TP concentrations have been near (within 0.02 mg/L) or below the standard since 2001, with the exception of values measured in Incline Creek in 2003 and 2006, and Third Creek in 2002. Overall, data from four of the five Nevada streams showed little or no trend in annual average TP concentration (see figure above). Third Creek shows an improving trend, possibly due to the dissipation of sediment from a 1986 avalanche and the rerouting of the Rosewood Creek tributary in the early 2000s. In California, Trout Creek, the Upper Truckee River, and General Creek show low but relatively stable average TP concentrations that exceed the 0.015 mg/L standard by minimal or modest amounts in all years. Blackwood and Ward creeks exceeded the standard by the greatest amounts, and the magnitudes of exceedance from the standard were higher in wetter years. Overall, the data from four of the five California streams showed moderate declines (i.e., improvements) in annual average TP concentrations. General Creek shows no trend in annual average TP concentrations (see figure above).

Confidence –

Status – There is high confidence in the reliability of the TP concentration data as the data collection consistently followed national field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). All field and laboratory data are subject to extensive quality assurance requirements (USGS 2006). Currently, a total of 20-35 individual samples are collected each water year from each of the ten monitored streams. This sampling frequency is considered sufficient to characterize different inflow conditions observed during the water year. The sampling frequency has varied over the period of record. The stream monitoring program focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). The analytical methods for measuring nutrients have been developed and customized for

use in aquatic systems where concentrations can be extremely low (Goldman et al. 2009). Thus, there is high confidence in the status determination.

Trend – Confidence in the trend determination is considered "low". Although there is high confidence in the data, assessments and interpretations of trend are all based on visual inspection (i.e., qualitative).

Overall – Overall confidence in the status and trend determination is moderate given the high confidence in status and the low confidence in trend.

Interim Target – Based on visual inspection of the data record, at least three of ten monitored streams should be in compliance with the applicable TP concentration Threshold Standard by the next major evaluation (Incline Creek appears closest to attaining the established standard).

Target Attainment Date – Based on the data record that indicates the Tahoe Region has never achieved the California standard for TP concentrations, it appears unlikely that monitored streams will ever achieve the adopted California standards. This suggests the State of California may need to review and possibly revise its standard based on the data record. For Nevada streams, challenges still exist for Incline Creek and Glenbrook Creek. Assuming actions to reduce phosphorus are implemented (e.g., phase-out of phosphorus-containing fertilizers, reduce erosion of natural sediment containing phosphorus), it is estimated that all streams in Nevada could be in attainment by 2031.

Human and Environmental Drivers – Within the Tahoe Basin, all the tributaries deliver sediment and nutrients to a single downstream water body, Lake Tahoe. Lake Tahoe has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the Lake from west to east, where precipitation can be twice as high on the West Shore relative to the East Shore. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain nutrients. Landscape disturbances including but not exclusive to impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the Lake or its tributaries. Weather variations and long-term climate change are considered to be among the most important environmental drivers of tributary runoff.

Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to provide a Basin-wide evaluation of sediment and nutrient input from tributaries to Lake Tahoe, and to support research efforts that aim to understand the drivers affecting the transparency of Lake Tahoe. Ten streams have been monitored since the early 1990s; five in California (Upper Truckee River and Trout, General, Blackwood, and Ward Creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood Creeks). Six of these streams have been monitored since water years 1980 or 1981. A few of the ten streams have had multiple monitoring stations along the tributary and all have primary monitoring stations at or near the point of stream discharge to Lake Tahoe. Currently, a total of 20-35 individual samples are collected each water year from each of the monitoring stations. The 10 primary stations allow for the evaluation of the cumulative conditions within the watershed and represent approximately 50 percent of the yearly tributary inflow into Lake Tahoe (Lahontan 1995). U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Other water quality-related constituents monitored include water and air temperature, pH, specific conductance, and dissolved oxygen.

Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, and U.S. Forest Service (Lake Tahoe Basin Management Unit).

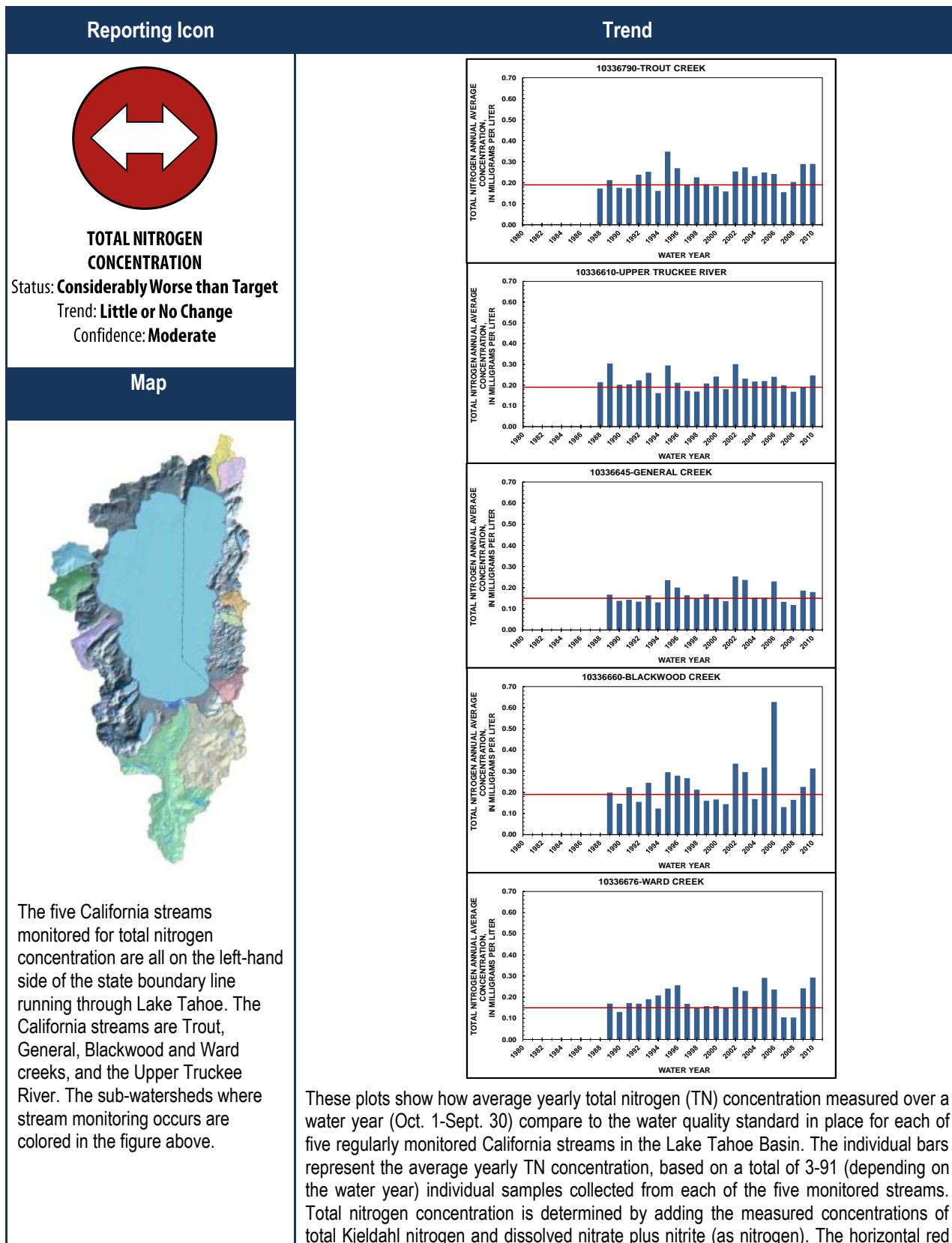
Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property water quality BMPs, required implementation of fertilizer management plans for significant recreation sites, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects

Effectiveness of Programs and Actions – Sufficient data do not exist to quantitatively evaluate the effectiveness of any individual program or action implemented to improve the quality of Lake Tahoe Basin tributary waters. Although each of the programs and actions are thought to aid in improving (or preserving) tributary water quality, the signal from any of these individual actions cannot be discerned due to year-to-year variability in total phosphorus loads, which are thought to be primarily driven by year-to-year variability in annual precipitation. However, based on the reduction in exceedances of adopted TP concentration Threshold Standards, it appears that, overall, the *Regional Plan* has contributed to the improving trend (i.e., fewer exceedances of adopted Threshold Standards) for total phosphorus.

Recommendations for Additional Actions – TRPA, in collaboration with federal, state, and local agencies, should pursue the

strategies and actions identified in the Lake Tahoe TMDL with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2026. TRPA's near-term implementation role should focus on program areas that it has the existing authority to lead: 1) accelerating implementation of its water quality BMP retrofit regulations including implementation of area-wide stormwater treatment strategies, 2) pursuing innovative redevelopment strategies that aim to accelerate water quality improvements, and 3) reducing atmospheric sources of pollutants known to impact aquatic habitats. In addition, TRPA should consider developing a policy to phase out the commercial sale and application of phosphorus-containing fertilizers, considering that the California standard has never been attained over the monitoring record and there continues to be exceedances of the adopted Nevada standard.

Tributaries: Total Nitrogen Concentration



line represents the California numeric standard for average TN concentration: 0.15 milligrams per liter (mg/L) for General and Ward Creeks, and 0.19 mg/L for Blackwood and Trout Creeks, and the Upper Truckee River. Nevada does not have a numerical TN standard for tributaries to Lake Tahoe. Stream monitoring data used to evaluate TN concentrations are from the sampling locations closest to where the tributaries discharge to Lake Tahoe. Data are from the Lake Tahoe Interagency Monitoring Program (LTIMP).

Data Evaluation and Interpretation

Relevance – Nitrogen is a nutrient important to the growth and reproduction of plants, and it is considered a pollutant of concern in the Lake Tahoe Basin (Lahontan and NDEP 2010). The majority of nitrogen entering Lake Tahoe is from atmospheric sources. Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (TERC 2011a). Free-floating algae (i.e., phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis and scattering light. Attached algae (i.e., periphyton) coat rocks in the near shore, adversely impacting near shore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). Under the Federal Clean Water Act and in California under the Porter-Cologne Act, each state develops a set of water quality standards designed to protect the beneficial uses of a waterbody. In the Tahoe Basin, Lahontan Regional Water Quality Control Board (CA), Nevada Division of Environmental Protection (NV), and TRPA have the individual authority to determine if standards have been violated.

Threshold Category – Water Quality

Indicator Category – Tributaries

Adopted Standard – Attain applicable state standards for concentrations of dissolved inorganic nitrogen; California does not have a standard for dissolved inorganic nitrogen, but does for Total Nitrogen: 0.15 milligrams per liter (mg/L) for General and Ward Creeks, and 0.19 mg/L for Blackwood and Trout Creeks, and the Upper Truckee River. Nevada does not have a numeric TN concentration standard for tributaries to Lake Tahoe.

Type of Standard – Numerical

Indicator (Unit of Measure) – The Indicator is average total nitrogen (TN) concentration measured over a water year (Oct. 1-Sept. 30). Average TN concentration is based on a total of 20-35 individual samples currently collected each water year from each of the five monitored streams in California, although the number of individual samples collected each water year has varied during the period of record from three to 91. Total nitrogen concentration is determined by adding the measured concentrations of total Kjeldahl nitrogen and dissolved nitrate plus nitrate (as nitrogen). The annual average TN concentration values presented here differ from the flow-weighted concentrations, in that the former value is the straight arithmetic mean of the measured values within a given water year regardless of inflow. All annual average TN concentrations are reported in milligrams per liter (mg/L).

Status – In the table below, scores for annual average TN concentration status, trend, and confidence were assigned for each of the five regularly monitored California streams in the Lake Tahoe Basin. Assigned scores for individual streams and overall status, trend, and confidence were based on: 1) percent to target calculations, 2) standard exceedance rate (see also Appendix WQ-1), 3) visual inspection of the graphed data record, and 4) the aggregation methods described in the Methodology Chapter of this report. The annual average TN concentrations in water year 2010 for the five regularly monitored streams in California ranged from 0.18 mg/L (General Creek, 20 percent greater than standard) to 0.31 mg/L (Blackwood Creek, 63 percent greater than the standard). The status of annual average tributary TN concentrations were determined to be “considerably worse than the target” because all five monitored streams exceeded the relevant established standard by between 20 percent and 93 percent (Appendix WQ-1 and figure above).

Stream	Status	Trend	Confidence
Trout	-4	-2	0
Upper Truckee	-4	0	0
General	-2	0	0
Blackwood	-4	2	0
Ward	-4	2	0

Overall Average	-3.6	0.4	0
Overall Narrative Assessment	Considerably Worse than Target	Little or no change	Moderate

Trends – Between water years 1989 and 2010, the average TN concentrations for the five regularly monitored streams in California ranged from 0.10 (67 percent of the standard) to 0.29 mg/L (93 percent greater than the standard) in General and Ward creeks, respectively and from 0.12 (63 percent of the standard) to 0.63 mg/L (332 percent greater than the standard) in Trout Creek, Upper Truckee River, and Blackwood Creek (see also appendix WQ-1). Annual average Total Nitrogen concentrations relative to the Numerical Standard differed from that observed for total phosphorus (TP). TP in the California streams exceeded the Numerical Standard in all years; however, it was common for the average TN concentration to vary among years above, at, or below the relevant standard. The patterns for TN and TP concentrations are not expected to be the same, since TN is comprised primarily of dissolved organic nitrogen (Coats and Goldman 2001), which is not directly associated with soil erosion, but is associated largely with microbial processing of vegetative biomass. For General Creek, TN was near (within 0.02 mg/L), at, or below the 0.15 mg/L value in about 68 percent of the years for which data are available. Ward Creek, with the same TN standard of 0.15 mg/L, was near, at, or below the standard in 55 percent of the years. Blackwood Creek, Trout Creek, and the Upper Truckee River, all with a TN standard of 0.19 mg/L, were near, at, or below the standard in about 50 percent of the years. There is no discernible long-term trend in average TN concentrations relative to the established standards. This finding is due to the observed variations in average TN concentrations within and among the five monitored streams, not due to insufficient data.

Confidence –

Status – There is high confidence in the reliability in the TN concentration data because the data collection consistently followed national field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). All field and laboratory data are subject to extensive quality assurance requirements (USGS 2006). Currently, a total of 20-35 individual samples are collected each water year from each of the five monitored streams. This sampling frequency is considered sufficient to characterize different inflow conditions observed during the water year. The sampling frequency has varied over the period of record. The stream monitoring program focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). The analytical methods for measuring nutrients have been developed and customized for use in aquatic systems where concentrations can be extremely low (Goldman et al. 2009). Thus, there is high confidence in the status determination.

Trend – Confidence in the trend determination is considered low. Although there is high confidence in the data, assessments and interpretations of trend are all based on inspection of graphed data (i.e., qualitative).

Overall Confidence – Overall confidence in the status and trend determination is “moderate” given the high confidence in status and the low confidence in trend.

Interim Target – Given that each stream in the data record attained the adopted standard in at least one water year suggests this standard is achievable. Therefore, it is estimated that at least one stream will attain the adopted TN concentration standard by the next evaluation in 2016.

Target Attainment Date – Considering that little or no change in annual average TN concentrations is evident in the monitoring record, estimating a target attainment date is problematic. A conservative estimate of attaining this standard is therefore set at 2031.

Human and Environmental Drivers – Within the Tahoe Basin, all the tributaries deliver sediment and nutrients to a single downstream water body, Lake Tahoe. Lake Tahoe has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the lake from west to east, where precipitation can be twice as high on the West Shore relative to the East Shore. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain nutrients. Landscape disturbances including, but not exclusive to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and degradation of stream environment zones, can contribute to sediment and nutrient inputs to the Lake or its tributaries. Weather variations and long-term climate change are considered among the most important environmental drivers of tributary runoff.

Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to provide a Basin-wide evaluation of sediment and nutrient input from tributaries to Lake Tahoe, and to support research efforts that aim to understand the drivers affecting the transparency of Lake Tahoe. Ten streams have been monitored since the early 1990s;

five in California (Upper Truckee River, and Trout, General, Blackwood, and Ward creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood Creeks). Six of these streams have been monitored since water years 1980 or 1981. A few of the ten streams have had multiple monitoring stations along the tributary, and all have primary monitoring stations at or near the point of stream discharge to Lake Tahoe. Currently, a total of 20-35 individual samples are collected each water year from each of the monitoring stations. The ten primary stations allow for evaluation of the cumulative conditions within the watershed and represent approximately 50 percent of the yearly tributary inflow into Lake Tahoe (Lahontan and NDEP 2010). U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Other water quality-related constituents monitored include water and air temperature, pH, specific conductance, and dissolved oxygen.

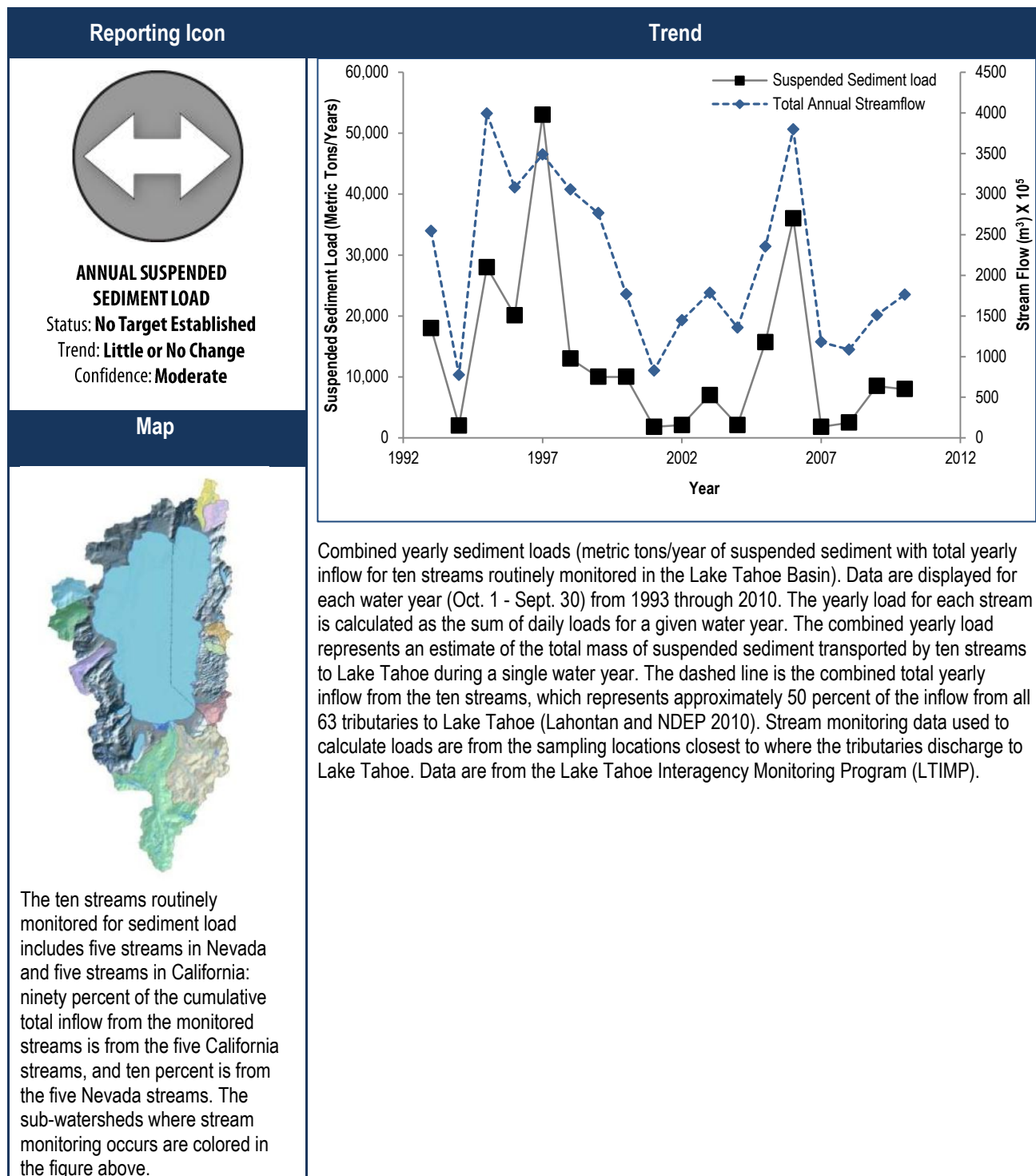
Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, and U.S. Forest Service (Lake Tahoe Basin Management Unit).

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property water quality BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and on-going allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects.

Effectiveness of Programs and Actions – Sufficient data do not exist to quantitatively evaluate the effectiveness of any existing individual program or action implemented to improve the quality of Lake Tahoe Basin tributary waters. Although each of the programs and actions are thought to aid in improving (or at least maintaining) tributary water quality, the signal from any of these individual actions cannot be discerned from the year-to-year variability in total nitrogen concentration measured at the watershed scale. Based on these data, total nitrogen concentrations are primarily driven by year-to-year variation in inflow, which is affected by annual precipitation. The status and trend determination suggests that actions have not been effective at reducing nitrogen concentrations to a level consistent with adopted Threshold Standards.

Recommendations for Additional Actions – TRPA, in collaboration with federal, state, and local agencies, should pursue the strategies and actions identified in the Lake Tahoe TMDL with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for annual average Lake Transparency by 2026. TRPA's near-term implementation role should focus on program areas that it has the existing authority to lead: 1) accelerating implementation of its water quality BMP retrofit regulations including implementation of area-wide stormwater treatment strategies, 2) pursuing innovative redevelopment strategies that aim to accelerate water quality improvements, 3) SEZ restoration and enhancement through the EIP (prioritized to tributary sources with the greatest pollutant load contribution), and 4) reducing atmospheric sources of pollutants known to impact aquatic habitats.

Tributaries: **Suspended Sediment Load**



Data Interpretation and Evaluation

Relevance – This indicator measures how much suspended sediment is delivered to Lake Tahoe via ten regularly monitored streams (measured as suspended sediment load). Sediment (particularly fine sediment) delivered to Lake Tahoe is known to directly affect the transparency of Lake Tahoe (Swift et al. 2006). The protection and restoration of the Lake's transparency is a central environmental goal, and Lake transparency is considered a key socioeconomic value. The tributaries have been identified as one of four source categories of pollutants (i.e., sediment and nutrient) loading to the Lake (Lahontan and NDEP 2010). LTIMP stream monitoring data are used to evaluate the status and trend of tributary loading of sediment and nutrients to Lake Tahoe. Long-term stream monitoring is also important to detect changes in water quality that may occur as a result of watershed restoration, or as a result of uncontrollable drivers such as weather and climate change.

Threshold Category – Water Quality

Indicator Category – Tahoe Basin Tributaries

Adopted Standard – 1) Tributaries: reduce total yearly nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe; 2) Littoral and Pelagic Lake Tahoe: decrease sediment load as required to attain turbidity values not to exceed three NTU (Nephelometric Turbidity Units). In addition, turbidity shall not exceed one NTU in shallow waters of the Lake not directly influenced by stream discharges (load reduction needed to attain standard, not provided).

Type of Standard: Management (for Tributaries); one Numerical Standard (related to sediment for Littoral Zone)

Indicator (Unit of Measure): The yearly load for each stream is calculated as the sum of daily loads for a given water year. Currently, a total of 20-35 individual samples are collected each water year from each of the ten streams. The combined yearly load represents an estimate of the total mass of suspended sediment transported by ten streams to Lake Tahoe during a single water year. Indicators measured include suspended sediment load (expressed as metric tonnes/year, metric tons/year, or MT/yr¹) and fine sediment particle load (expressed as number of particles/yr). Fine sediment particles are less than 16 microns in diameter.

Status – The combined yearly suspended sediment (SS) load for water year (WY) 2010 was 7,649 MT. The combined yearly load of fine sediment particles for WY 2010 was 2.45×10^{19} particles. The total yearly inflow for all ten streams was 176,000,000 (or $1,760 \times 10^5$) cubic meters in WY 2010. SS loads were largely driven by annual loads from Blackwood and Ward creeks, and the Upper Truckee River. Together they contributed 76 percent of the average load from all ten streams (Appendix WQ-2). Fine sediment particle loads were largely driven by the yearly loads from the Upper Truckee River, and Blackwood and Trout creeks, which together contributed 78 percent of the average yearly load from all ten streams (Appendix WQ-2). There is no clearly established Numerical Standard (target) for suspended sediment or fine sediment particle loads, resulting in a status determination of "unknown."

Trends – Tributary sediment loads are a function of concentration and amount of inflow (which is a function of annual precipitation). Combined yearly tributary loads of suspended sediment and fine sediment particles are strongly influenced by inflow, and in the Lake Tahoe Basin there can be considerable year-to-year variation in combined total yearly inflow from the ten monitored streams (Appendix WQ-2). Tributary inflow depends on the amount and timing of precipitation (snow and rain) that falls in each watershed. Factors such as air temperature and snowmelt, rain-on-snow events, and rain versus snow, all affect the timing of inflow within the water year. Subsurface infiltration and stormwater discharge from developed areas also affects tributary flows; thus, estimates of sediment load presented here represent an unknown proportion of non-urban and urban sources. There are circumstances where yearly load does not relate well to yearly stream flow. This is usually associated with water years that have a large rain-on-snow event (e.g., 1997 and 2006). These events can be intense and erosive, generating more material than other runoff events such as spring snowmelt runoff.

From water years 1993 to 2010, the total yearly inflow ranged from 772 to 3990×10^5 cubic meters. During the 18-year period, total yearly inflow was highest in water years 1995 through 1998, and 2006, and was above 3000×10^5 cubic meters in those water years. Inflow was extremely high in water year 1997 when a huge rain-on-snow event caused massive flooding, especially on the West Shore. These types of large hydrologic events have the capacity to transport significant amounts of material to the Lake as they are intensive and erosive. For the period 1999-2010, total yearly inflow was moderate to low, ranging from 827 to 2770×10^5 cubic meters, except for the large total yearly inflow in water year 2006—the result of a large New Year's rain-on-snow event. Water Years 1994, 2001, 2002, 2004, and 2007 to 2009, were characterized by low total yearly inflow (less than 1500×10^5 cubic meters) from the ten monitored streams.

The combined yearly SS loads for the ten monitored streams during water years 1993-2010 ranged from a low of 1,000-2,000 Metric Tons in 1994, 2001, 2002, 2004, and 2007, to greater than 50,000 MT in 1997. Generally, there is a strong positive

¹ Metric ton = 2,205 pounds

relationship between total yearly inflow and combined yearly suspended sediment load for the ten streams, with the notable exception of water year 1997, when the ratio of suspended sediment load to flow was higher than in other years. Flow-weighted concentration in 1997 also increased by a factor of two or more relative to the other water years, except 2006. The values measured in 1997 are thought to be a direct result of increased erosion during the extreme 1997 rain-on-snow event.

The evaluation of trend in sediment loads from tributaries to Lake Tahoe is complicated by the large inter-annual variability in precipitation and inflow and the response of individual streams. It would be erroneous to make conclusions based on apparent short-term trends in combined yearly loads, given the known variability in yearly inflow. Yearly flow-weighted concentrations (FWC) of sediment were calculated to investigate long-term pollutant loading trends in the presence of variable inflows (Appendix WQ-3). Further, a five-year moving average of sediment FWC was constructed to help reveal long-term trends. While the five-year moving average of sediment FWC appears to decline after the early 2000s, this is more a function of the moving average being influenced by the large 1997 inflow peak and the associated, elevated FWC. Thus, visual inspection of the five-year moving average suggests no trend in FWC of suspended sediment, and this observation was used to establish a trend of “little or no change” in suspended sediment load.

The load of fine sediment particles less than 16 microns in diameter has only been measured since water year 2002. Yearly combined fine sediment particle loads for the ten streams during water years 2002 - 2010 ranged from 0.473×10^{19} particles in 2002 to 9.88×10^{19} particles in 2006. Combined yearly fine sediment particle loads generally follow a similar pattern as SS loads. However, the ratio of SS load to fine sediment particle load for any particular year appears to depend on the general magnitude of flow, except for water years 2006 and 2008, which had the highest and lowest total yearly inflows, respectively, in the 2002-2010 period. Overall, fine sediment particle loads exhibit no clear trend either in the aggregate or in the individual streams (Appendix WQ-2).

Confidence –

Status – There is high confidence in the reliability of the data used to calculate yearly loads as the data collection consistently followed national field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). All field and laboratory data are subject to extensive quality assurance requirements (USGS 2006). The stream monitoring program focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). The analytical methods for measuring fine sediment particles has been developed and customized for use in aquatic systems where concentrations can be extremely low (Goldman et al. 2009).

Trend – There is high confidence in the reliability of the data used to calculate yearly flow-weighted concentrations as the data collection followed national and consistent field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). However, a visual inspections of the five-year moving average was used to estimate the long-term trend in suspended sediment load, yielding a “low” confidence in trend assessment.

Overall – Because there is high confidence in status and low confidence in trend, the overall confidence was determined to be “moderate.”

Interim Target – It is not possible to establish an interim SS load target given the high variability resulting from variable stream inflow.

Target Attainment Date – Because this is a management standard with vaguely defined targets, one cannot reasonably predict when this Threshold Standard will be “attained.” The agency should continue to support stream monitoring to demonstrate trend in SS load.

Human and Environmental Drivers – Within the Tahoe Basin, all the tributaries deliver sediment and nutrients to a single downstream water body, Lake Tahoe. Lake Tahoe has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the lake from west to east, where precipitation can be twice as high on the West Shore relative to the East Shore. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain nutrients. Landscape disturbances including, but not exclusive to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and the degradation of stream environment zones, can contribute to sediment and nutrient inputs to the Lake or its tributaries. Weather variations and long-term climate change are considered among the most important environmental drivers of tributary runoff.

Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to provide a Basin-wide evaluation of sediment and nutrient input from tributaries to Lake Tahoe, and to support research efforts that aim to understand the drivers affecting the transparency of Lake Tahoe. Ten streams have been monitored since the early 1990s;

five in California (Upper Truckee River, and Trout, General, Blackwood and Ward Creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood creeks). Six of these streams have been monitored since water years 1980 or 1981. A few of the ten streams have had multiple monitoring stations along the tributary and all have primary monitoring stations at or near the point of stream discharge to Lake Tahoe. Currently, a total of 20-35 individual samples are collected each water year from each of the monitoring stations. The ten primary stations allow for the evaluation of the cumulative conditions within the watershed and represent approximately 50 percent of the yearly tributary inflow into Lake Tahoe (Lahontan and NDEP 2010). Reporting of combined yearly loads begins in water year 1993 because that was when the 10th stream was included in the monitoring program. U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Other water quality-related constituents monitored include water and air temperature, pH, specific conductance, and dissolved oxygen.

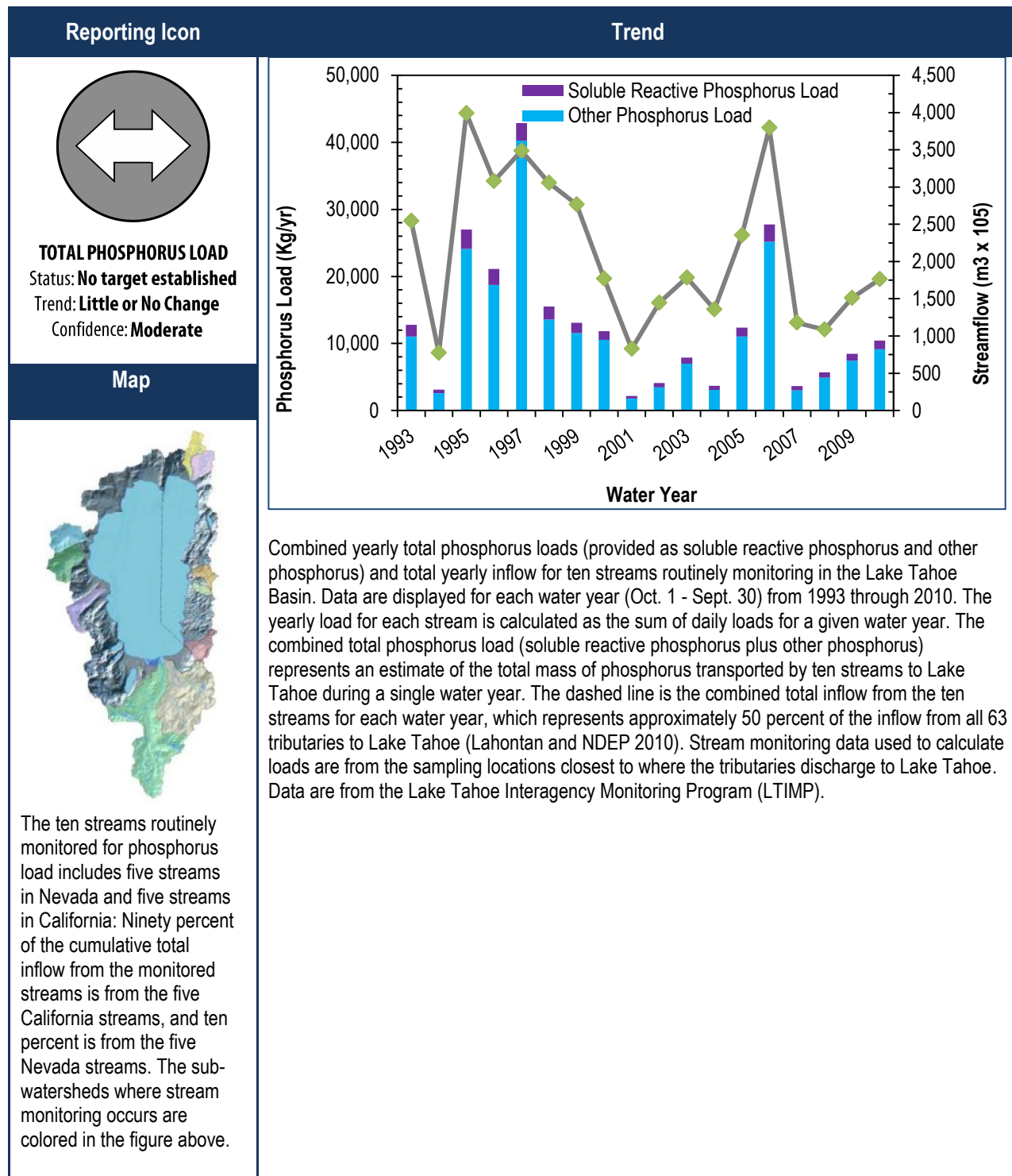
Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, and U.S. Forest Service – Lake Tahoe Basin Management Unit.

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects

Effectiveness of Programs and Actions – No data exist to quantitatively evaluate the effectiveness of any individual policy, program or action implemented to improve the quality of Lake Tahoe Basin tributary waters. Although each of the programs and actions are thought to aid in improving (or preserving) tributary water quality, the signal from any of these individual actions cannot be discerned from the year-to-year variability in sediment loads monitored as part of the LTIMP Tributary monitoring program. Although there is high inter-annual variability associated with SS load, and SS loads are strongly related to stream flow, there is some evidence to suggest that pollutant contributions have shown little or no change when natural variations in inflow are accounted for. Suspended sediment loads should continue to be monitored, and a more sophisticated trend analysis should be conducted.

Recommendations for Additional Actions – TRPA, in collaboration with federal, state, and local agencies, should pursue the strategies and actions identified in the Lake Tahoe TMDL with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2026. TRPA's near-term implementation role should focus on program areas that it has the existing authority to lead: 1) accelerating implementation of its water quality BMP retrofit regulations including implementation of area-wide stormwater treatment strategies, 2) pursuing innovative redevelopment strategies that aim to accelerate water quality improvements, 3) SEZ restoration and enhancement through the EIP (prioritized to tributary sources with the greatest pollutant load contribution), and 4) reducing atmospheric sources of pollutants known to impact aquatic habitats. In addition, TRPA should work with the science community to develop quantitative pollutant standards for Tahoe Basin streams that take into account the large natural variation in yearly stream inflow.

Tributaries: Total Phosphorus Load



Data Evaluation and Interpretation

Relevance – This indicator measures how much phosphorus is delivered to Lake Tahoe via monitored streams (measured as phosphorus load). Phosphorus is a nutrient important to the growth and reproduction of plants, and it is considered a pollutant of concern in the Lake Tahoe Basin (Lahontan and NDEP 2010). Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (TERC 2011a). Free-floating algae (i.e., phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis and scattering light. Attached algae coat rocks in the near shore, adversely impacting near shore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). Soluble reactive phosphorus approximates the amount of orthophosphate that is directly available for use by plants, whereas total phosphorus includes all forms of phosphorus that are directly and indirectly available to plants. Phosphorus occurs naturally in the soils of the Lake Tahoe Basin, and is delivered to surface waters and Lake Tahoe through soil erosion and fertilizer runoff (Lahontan and NDEP 2010).

Threshold Category – Water Quality

Indicator Category – Tributaries

Adopted Standards: 1) Tributaries: reduce total yearly nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe; 2) Littoral and Pelagic Lake Tahoe related standards for nutrient and sediment including: a) reduce dissolved inorganic nitrogen (N) loading from all sources by 25 percent of the 1973-81 annual average; b) reduce dissolved inorganic nitrogen loads from surface runoff by approximately 50 percent, from groundwater approximately 30 percent, and from atmospheric sources approximately 20 percent of the 1973-81 annual average; and c) reduce the loading of dissolved phosphorus, iron, and other algal nutrients from all sources, as required, to achieve ambient standards for primary productivity and transparency

Type of Standard – Management (Tributaries); for Littoral and Pelagic Lake Tahoe: Numerical Standards and Management Standards with numeric targets

Indicator (Unit of Measure) – The yearly load for each stream is calculated as the sum of daily loads for a given water year. Currently, a total of 20-35 individual samples are collected each water year from each of the ten streams. The combined yearly load represents an estimate of the total mass of the constituent transported by ten streams to Lake Tahoe during a single water year. Indicators measured include total phosphorus load (expressed as kilograms per year; kg/yr) and soluble reactive phosphorus (expressed as kilograms as phosphorus per year; kg as P/yr).

Status – The combined yearly load for total phosphorus (TP) was 10,424 kg in water year (WY) 2010. The soluble reactive phosphorus (SRP) load for WY 2010 was 1,292 kg as P. The total yearly inflow for all ten streams was 176,000,000 (or $1,760 \times 10^5$) cubic meters in WY 2010. The WY 2010 load estimates are similar to the combined yearly load estimates for WY 2000, which had a similar level of total yearly inflow. TP and SRP loads were largely driven by the yearly loads from the Upper Truckee River, and Trout, Blackwood, and Ward creeks. Together these streams contributed 85 percent and 80 percent of the average yearly TP and SRP loads, respectively, from all ten streams (Appendix WQ-2). There is no well-defined Numerical Standard (numeric target) for TP or SRP loads, so no status determination was provided.

Trends – Tributary phosphorus loads are a function of the constituent concentration and amount of inflow. Combined yearly tributary loads of total phosphorus (TP) and soluble reactive phosphorus (SRP) are strongly influenced by inflow, and in the Lake Tahoe Basin there can be considerable year-to-year variation in combined total yearly inflow from the ten monitored streams. Tributary flows depend on the amount and timing of precipitation (snow and rain) that falls in each watershed. Factors such as air temperature and snowmelt, rain-on-snow events, and rain versus snow all affect the timing of inflow within the water year. Subsurface infiltration and stormwater discharge from developed areas also affect tributary flows; thus, estimates of phosphorus load presented here represent some combination of non-urban and urban sources.

From water years 1993 to 2010, the total yearly inflow ranged from 772 to 3990×10^5 cubic meters. During the 18-year period, total yearly inflow was highest in water years 1995 through 1998, and 2006, and was above 3000×10^5 cubic meters in those water years. Inflow was extremely high in water year 1997 when a huge rain-on-snow event caused massive flooding, especially on the West Shore. These types of large hydrologic events have the capacity to transport significant amounts of material to the Lake as they are intensive and erosive. For the period 1999-2010, total yearly inflow was moderate to low, ranging from 827 to 2770×10^5 cubic meters, except for the large total yearly inflow in water year 2006—the result of a large New Year's rain-on-snow event. Water Years 1994, 2001, 2002, 2004, and 2007 to 2009, were characterized by low total yearly inflow (less than 1500×10^5 cubic meters) from the 10 monitored streams.

The combined yearly TP loads for the ten monitored streams during water years 1993-2010 ranged from 2,180 kg in 2001 to 42,900 kg in 1997. Generally, combined yearly TP loads varied directly with total yearly inflow. Water year 1997 is a notable

exception, which is thought to be due to increased erosion during an extreme rain-on-snow event. The pattern of combined yearly TP loads during water years 1993-2010 was similar to suspended sediment (SS) loads (see also Appendix WQ-2). This is expected since phosphorus is attached to soil sediment and transported along with SS.

The evaluation of trend in total phosphorus loads from tributaries to Lake Tahoe is complicated by large inter-annual variability in precipitation and inflow, and the response of individual streams. It would be erroneous to make conclusions based on apparent short-term trends in combined yearly loads, given the known variability in yearly inflow. Yearly flow-weighted concentrations (FWC) of total phosphorus were calculated to investigate long-term pollutant loading trends in the presence of variable inflows (Appendix WQ-3). Further, a five-year moving average of sediment FWC was constructed to help reveal long-term trends. The combined yearly FWC for TP followed a similar pattern to suspended sediment. Phosphorus adsorbs to soils and the two are typically transported together. Even though there are periods over the 1993-2010 record where the five-year moving average shows signs of either improvement or degradation, there is no observable overall trend.

The combined yearly SRP loads for the ten monitored streams during water years 1993-2010 ranged from 411 kg as P in 2001 to 2,880 kg as P in 1995. The year-to-year variations in combined yearly SRP loads generally tracked the combined yearly TP loads. The average ratio of SRP to TP combined yearly load was 13 percent, and the ratio ranged from 6-19 percent throughout the period of record. Water Years 1997 and 2006 had the lowest SRP to TP ratios of 6-9 percent, respectively. It is hypothesized that the time needed for the phosphorus attached to suspended sediment to detach and reach equilibrium with the stream water, was longer than the time of travel during the rapid inflow that occurred during the huge rain-on-snow events in those years. The five-year moving average of SRP showed a decline between 1997 and 2005, an increase from 2006 to 2010, but showed no observable overall trend (Appendix WQ-3).

A determination of little or no change in the overall trend of phosphorus load is based on no observable trend in the FWC of TP.

Interim Target – It is not possible to establish an interim SS load target given the high variability resulting from variable stream inflow.

Target Attainment Date – Because this is a Management Standard with vague targets, one cannot reasonably predict when this Threshold Standard will be “attained.” The agency should continue to monitor to demonstrate a decline TP load trend.

Confidence –

Status – There is high confidence in the reliability of the data used to calculate yearly phosphorus loads as the data collection consistently followed national field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). All field and laboratory data are subject to extensive quality assurance requirements (USGS 2006). Currently, a total of 20-35 individual samples are collected each water year from each of the ten monitored streams. This sampling frequency is considered sufficient to characterize different inflow conditions observed during the water year. The sampling frequency has varied over the period of record. The stream monitoring program focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). The analytical methods for measuring nutrients has been developed and customized for use in aquatic systems where concentrations can be extremely low (Goldman et al. 2009).

Trend – There is high confidence in the reliability of the data used to calculate yearly flow-weighted concentrations as the data collection followed national and consistent field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). However, visual inspections of the five-year moving average was used to estimate the long-term trend in TP and SRP loads, yielding a “low” confidence in trend assessment. **Overall:** Because there is high confidence in status and low confidence in trend, the overall confidence was determined to be “moderate.”

Human and Environmental Drivers – Within the Tahoe Basin, all the tributaries deliver sediment and nutrients to a single downstream water body, Lake Tahoe. Lake Tahoe has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the lake from west to east, where precipitation can be twice as high on the West Shore relative to the East Shore. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain nutrients. Landscape disturbances including, but not exclusive to, impervious road and parking lot surfaces, residential and commercial development, excess fertilizer application, wildfire, and degradation of stream environment zones, can contribute to sediment

and nutrient inputs to the Lake or its tributaries. Weather variations and long-term climate change are considered among the most important environmental drivers of tributary runoff.

Monitoring Approach – The LTIMP stream monitoring program was first developed in 1979 to provide a Basin-wide evaluation of sediment and nutrient input from tributaries to Lake Tahoe, and to support research efforts that aim to understand the drivers affecting the transparency of Lake Tahoe. Ten streams have been monitored since the early 1990s; five in California (Upper Truckee River, and Trout, General, Blackwood and Ward creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood creeks). Six of these streams have been monitored since water years 1980 or 1981. A few of the ten streams have had multiple monitoring stations along the tributary and all have primary monitoring stations at or near the point of stream discharge to Lake Tahoe. Currently, a total of 20-35 individual samples are collected each water year from each of the monitoring stations. The 10 primary stations allow for the evaluation of the cumulative conditions within the watershed and represent approximately 50 percent of the yearly tributary inflow into Lake Tahoe (Lahontan and NDEP 2010). Reporting of combined yearly loads begins in water year 1993 because that was when the 10th stream was included in the monitoring program. U.S. Geological Survey gauging stations are located at each of the monitoring stations, where inflow (discharge) measurements are collected and continuous inflow is calculated. Other water quality-related constituents monitored include water and air temperature, pH, specific conductance, and dissolved oxygen.

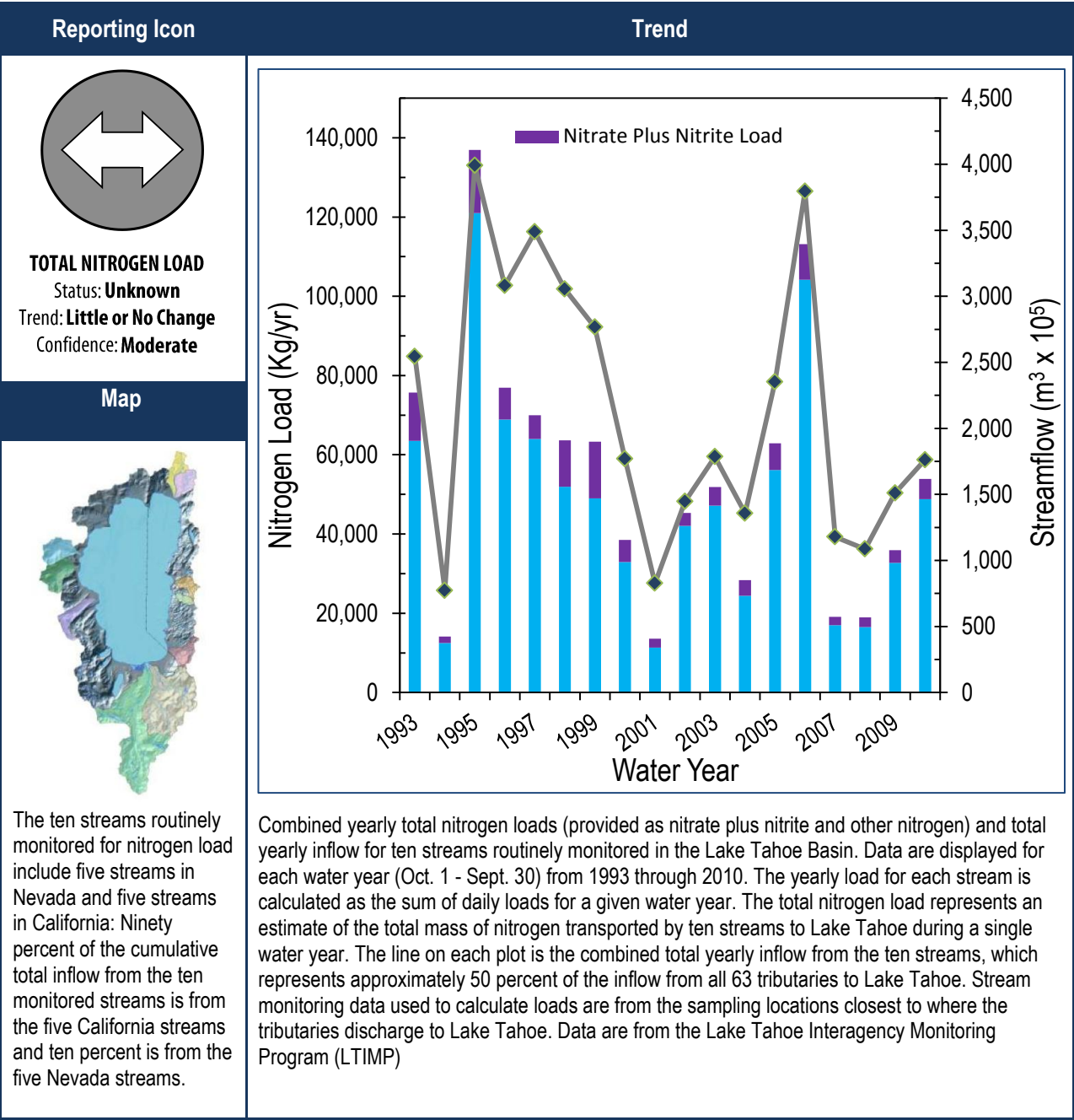
Monitoring Partners – U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, and U.S. Forest Service – Lake Tahoe Basin Management Unit.

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and ongoing allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects

Effectiveness of Programs and Actions – Insufficient data exists to quantitatively evaluate the effectiveness of any individual program or action implemented to improve the quality of Lake Tahoe Basin tributary waters. High inter-annual variability in loads, which is thought to be primarily driven by variability in annual precipitation, complicates the determination of overall effectiveness of the *Regional Plan* and actions taken by Regional partners. Although each of the programs and actions are thought to aid in improving (or at least maintaining) tributary water quality, the signal from any of these individual actions cannot be discerned from the year-to-year variability in phosphorus loads monitored at the watershed scale as part of the LTIMP tributary monitoring program. Based on visual inspection of the overall long-term trend, it appears that compliance measures adopted in the *Regional Plan* and actions taken by Regional partners, have at least maintained water quality because tributary phosphorus loads show no signs of increase. Total Phosphorus loads should continue to be monitored, and a more sophisticated trend analysis should be conducted to better understand trends.

Recommendations for Additional Actions – TRPA, in collaboration with federal, state, and local agencies, should pursue the strategies and actions identified in the Lake Tahoe TMDL with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2026. TRPA's near-term implementation role should focus on program areas that it has the existing authority to lead: 1) accelerating implementation of its water quality BMP retrofit regulations including implementation of area-wide stormwater treatment strategies, 2) pursuing innovative redevelopment strategies that aim to accelerate water quality improvements, 3) reducing atmospheric sources of pollutants known to impact aquatic habitats, 4) SEZ restoration and enhancement through the EIP (prioritized to tributary sources with the greatest pollutant load contribution), and 5) phasing out the use of phosphorus containing fertilizers. In addition, TRPA should work with the science community to develop quantitative pollutant standards for Tahoe Basin streams that take into account the large natural variation in yearly stream inflow.

Tributaries: Nitrate and Nitrite (and Total Nitrogen) Load



Data Evaluation and Interpretation

Relevance – This indicator measures how much nitrogen is delivered to Lake Tahoe via monitoring streams (measured as nitrogen load). Nitrogen is a nutrient important to the growth and reproduction of plants, and it is considered a pollutant of concern in the Lake Tahoe Basin (Lahontan and NDEP 2010). Nitrogen and phosphorus together support the growth of algae in Lake Tahoe (TERC 2011a). Free-floating algae (i.e., phytoplankton) occur throughout Lake Tahoe and contribute to the decline in water transparency by absorbing light for photosynthesis. Attached algae (i.e., periphyton) coat rocks in the near shore adversely impacting near shore aesthetics. From an ecological perspective, algae are a dominant component of the aquatic food web, providing an important source of energy and nutrients that support other organisms in the food web (e.g., zooplankton and herbivorous fish). Nitrate and nitrite are inorganic forms of nitrogen that are directly available for use by plants, whereas total nitrogen includes all organic and inorganic forms of nitrogen that are directly and indirectly available to plants. Nitrogen occurs naturally in the soils of the Lake Tahoe Basin to some extent, but organic nitrogen primarily comes from the decomposition of plant material. Atmospheric deposition is considered the primary source of inorganic nitrogen to Lake Tahoe (Lahontan and NDEP 2010).

Threshold Category – Water Quality

Indicator Category – Tributaries

Adopted Standard – 1) Tributaries: reduce total annual nutrient and suspended sediment load to achieve loading thresholds for littoral and pelagic Lake Tahoe; 2) Pelagic and Littoral Zones: a) reduce dissolved inorganic nitrogen (N) loading from all sources by 25 percent of the 1973-81 yearly average; and b) reduce dissolved inorganic nitrogen loads from surface runoff by approximately 50 percent, from groundwater approximately 30 percent, and from atmospheric sources, approximately 20 percent of the 1973-81 annual average

Type of Standard – Numerical

Adopted Standard – Reduce total yearly nutrient and suspended sediment load to achieve loading Threshold Standards for littoral and pelagic Lake Tahoe.

Type of Standard – Management

Indicator (Unit of Measure) – The yearly load for each stream is calculated as the sum of daily loads for a given water year. Currently a total of 20-35 individual samples are collected each water year from each of the 10 streams. The combined yearly load represents an estimate of the total mass of the constituent transported by ten streams to Lake Tahoe during a single water year. Nitrate plus nitrite (as nitrogen) values are used as estimates of the combined yearly dissolved inorganic nitrogen load. Indicators measured include total nitrogen (TN) load (expressed as kilograms per year; kg/yr), and nitrate plus nitrite as nitrogen load (expressed as kilograms as N per year; kg as N/yr)

Status – The combined yearly load for total nitrogen (TN) was 53,876 kilograms (kg) in water year (WY) 2010. The combined yearly load of nitrate plus nitrite, as nitrogen (N+N) was 5,110 kg as N in WY 2010. The total yearly inflow for all ten streams was 176,000,000 (or $1,760 \times 10^5$) cubic meters in WY 2010. The WY 2010 load estimates are similar to the yearly load estimates for WY 2003, which had a similar level of total yearly inflow. TN and N+N loads were largely driven by the yearly loads from the Upper Truckee River, and Trout, Blackwood, and Ward creeks. Together these streams contributed 82 percent and 85 percent of the average yearly TN and N+N loads, respectively, from all ten streams (Appendix WQ-2).

Trends – Tributary nitrogen loads are a function of the constituent concentration and amount of inflow. Combined yearly tributary loads of TN and N+N are strongly influenced by inflow, and in the Lake Tahoe Basin there can be considerable year-to-year variation in combined total yearly inflow from the ten monitored streams. Tributary flows depend on the amount and timing of precipitation (snow and rain) that falls in each watershed. Factors such as air temperature and snowmelt, rain-on-snow events, and rain versus snow, all affect the timing of inflow within the water year. Subsurface infiltration and stormwater discharge from developed areas also affect tributary flows; thus, estimates of nitrogen load presented here represent some combination of non-urban and urban sources.

From water years 1993 to 2010, the total yearly inflow ranged from 772 to 3990×10^5 cubic meters. During the 18-year period, total yearly inflow was highest in water years 1995 through 1998, and 2006, and was above 3000×10^5 cubic meters in those water years. Inflow was extremely high in water year 1997 when a huge rain-on-snow event caused massive flooding, especially on the West Shore. These types of large hydrologic events have the capacity to transport significant amounts of material to the Lake as they are intensive and erosive. For the period 1999-2010, total yearly inflow has been moderate to low, ranging from 827 to 2770×10^5 cubic meters, except for the large total yearly inflow in water year 2006 – the result of a large New Year's rain-on-snow event. Water Years 1994, 2001, 2002, 2004, and 2007 to 2009, were characterized by low total yearly inflow (less than 1500×10^5 cubic meters) from the 10 monitored streams.

The combined yearly TN loads for the ten monitored streams during water years 1993-2010 ranged from 13,600 kg in 2001, to 137,000 kg in 1995. Water year 2006 also had a large yearly TN load of 113,000 kg. Combined yearly TN load was highest in water year 1995, followed by 2006, whereas total phosphorus (TP) and suspended sediment (SS) combined yearly loads were highest in water year 1997, followed by 2006. TN yearly load was related to total yearly inflow for the combined streams.

The evaluation of trend in nitrogen loads from tributaries to Lake Tahoe is complicated by the large inter-annual variability in precipitation and inflow. It would be erroneous to make conclusions based on apparent short-term trends in combined yearly loads, given the known (and sometimes extreme) variability in yearly inflow. Yearly flow-weighted concentrations (FWC) of total phosphorus were calculated to investigate long-term pollutant loading trends in the presence of variable inflows (Appendix WQ-3). Further, a five-year moving average of sediment FWC was constructed to help reveal long-term trends. For water years 1993-2010, combined yearly FWC for TN for all ten streams ranged from 0.16 to 0.34 mg/L. While combined yearly FWC for TN exhibited inter-annual variability, there is no observable overall trend.

The combined yearly nitrate plus nitrite (N+N) loads for the ten monitored streams during water years 1993-2010 ranged from 1,640 kg as N in 1994, to 15,900 kg as N in 1995. Yearly N+N load for the 10 monitored streams was related to total yearly inflow, but not as closely as TN, suspended sediment (SS), and total phosphorus (TP) loads. Yearly N+N load peaks occurred in water years 1995 and 1999, whereas the peaks for TN occurred in 1995 and 2006, and TP and SS yearly load peaks occurred in 1997 and 2006. N+N can rapidly leach through soils. It is of biological origin and a by-product of vehicle emissions (NO_x). Erosion events are not as likely to be associated with N+N loading as they are with SS and TP loading; although N+N load will be affected by inflow since inflow is used to calculate loads. For water years 1993 to 2010, the ratio of N+N load to TN load ranged from 8 to 24 percent, and averaged 14 percent. Thus, the majority of the TN in the ten monitored streams occurs as organic nitrogen; both dissolved organic nitrogen and particulate organic nitrogen. For water years 1993-2010, combined yearly FWC for N+N for all ten LTIMP streams ranged from 0.017 to 0.052 mg/L as N. There was considerable inter-annual variability in the N+N combined yearly FWC between water years 1993-1999. However, since 2000, the variability has declined, with the five-year moving average dropping from 0.35 mg/L as N prior to 2000 to 0.023 mg/L as N in 2010.

A determination of "little or no change" in the overall trend of nitrogen load is based on no observable trend in the flow-weighted concentration of TN.

Confidence

Status – There is high confidence in the reliability of the data used to calculate yearly loads as the data collection consistently followed national field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). All field and laboratory data are subject to extensive quality assurance requirements (USGS 2006). Currently a total of 20-35 individual samples are collected each water year from each of the ten monitored streams. This sampling frequency is considered sufficient to sample during different inflow conditions observed during the water year. The sampling frequency has varied over the period of record. The stream monitoring program focuses on both event-based conditions (large runoff events associated with rainfall and snowmelt) and baseline conditions (low inflow during summer when precipitation is negligible). The analytical methods for measuring sediment, fine particles, and nutrients has been developed and customized for use in aquatic systems where concentrations can be extremely low (Goldman et al. 2009).

Trend – There is high confidence in the reliability of the data used to calculate yearly flow-weighted concentrations as the data collection followed national and consistent field monitoring protocols established by the U.S. Geological Survey for stream monitoring (USGS variously dated; Rowe et al. 2002). However, visual inspections of the five-year moving average was used to estimate the long-term trend in TP and SRP loads, yielding a "low" confidence in trend assessment.

Overall – Because there is high confidence in status and low confidence in trend, the overall confidence was determined to be "moderate."

Interim Target – Tributary nitrogen Load delivered to Lake Tahoe are expected to continue to vary with flow. Because loads fluctuate with precipitation, one cannot reasonably or accurately predict tributary N loads into the future. Thus, no interim target can be provided.

Target Attainment Date – Tributary nitrogen loads delivered to Lake Tahoe are expected to continue to vary with flow. Because loads fluctuate with precipitation, one cannot reasonably or accurately predict tributary N loads into the future. In addition, the Threshold Standard is vague in terms of how much tributary N load needs to be reduced. Consequently is unknown when this standard will be achieved.

Human and Environmental Drivers – Within the Tahoe Basin, all the tributaries deliver sediment and nutrients to a single

downstream water body, Lake Tahoe. Lake Tahoe has 63 individual tributaries and associated watersheds, each with their own drainage area, slope, geology, and land-use characteristics. Furthermore, variability in the amount, timing, and type of precipitation strongly influences runoff patterns. A substantial rain shadow exists across the lake from west to east, where precipitation can be twice as high on the West Shore relative to the East Shore. Both new and legacy disturbances to the landscape can affect the volume of runoff, erosion rates, and the ability of the watershed to retain nutrients. Landscape disturbances including, but not exclusive to, impervious road and parking lot surfaces, residential and commercial development, wildfire, and degradation of stream environment zones, can contribute to sediment and nutrient inputs to the Lake or its tributaries (Lahontan and NDEP 2010). Atmospheric sources are considered one of the most prevalent sources of nitrogen input into Lake Tahoe (Lahontan and NDEP 2010). Weather variations and long-term climate change are considered among the most important environmental drivers of tributary runoff.

Monitoring Approach — The LTIMP stream monitoring program was first developed in 1979 to provide a Basin-wide evaluation of sediment and nutrient input from tributaries to Lake Tahoe, and to support research efforts that aim to understand the drivers affecting the transparency of Lake Tahoe. Ten streams have been monitored since the early 1990s; five in California (Upper Truckee River, and Trout, General, Blackwood, and Ward Creeks) and five in Nevada (Third, Incline, Glenbrook, Logan House, and Edgewood Creeks). Six of these streams have been monitored since water years 1980 or 1981. A few of the ten streams have had multiple monitoring stations along the tributary and all have primary monitoring stations at or near the point of stream discharge to Lake Tahoe. Currently, a total of 20-35 individual samples are collected each water year from each of the monitoring stations. The ten primary stations allow for the evaluation of the cumulative conditions within the watershed and represent approximately 50 percent of the yearly tributary inflow into Lake Tahoe (Lahontan and NDEP 2010). Reporting of combined yearly loads begins in water year 1993 because that was when the 10th stream was included in the monitoring program. U.S. Geological Survey gauging stations are located at each monitoring station, where inflow (discharge) measurements are collected and continuous inflow is calculated. Other water quality-related constituents monitored include water and air temperature, pH, specific conductance, and dissolved oxygen.

Monitoring Partners — U.S. Geological Survey (Nevada and California Water Science Centers), University of California at Davis (Tahoe Environmental Research Center), Tahoe Regional Planning Agency, and U.S. Forest Service – Lake Tahoe Basin Management Unit.

Programs and Actions Implemented to Improve Conditions – Stream environment zone (SEZ) restoration and enhancement, urban growth control limits, best management practices (BMPs) to reduce nutrient and sediment discharge from disturbed soils, retrofit regulations for private and commercial property water quality BMPs, reducing private automobile use through improvements to public transit and alternative transportation modes (with the goal of reducing air pollution and the subsequent deposition of nitrogen and fine sediment), and on-going allocation of water quality mitigation funds to support erosion control and stormwater pollution control projects

Effectiveness of Programs and Actions — Insufficient data exists to quantitatively evaluate the effectiveness of any individual program or action implemented to improve the quality of Lake Tahoe Basin tributary waters. High inter-annual variability in loads, which is thought to be primarily driven by variability in annual precipitation, complicates the determination of overall effectiveness of the *Regional Plan* and actions taken by Regional partners. Although each of the programs and actions are thought to aid in improving (or at least maintaining) tributary water quality, the signal from any of these individual actions cannot be discerned from the year-to-year variability in nitrogen loads monitored at the watershed scale as part of the LTIMP tributary monitoring program. Based on visual inspection of the overall long-term trend, it appears that compliance measures adopted in the *Regional Plan* and actions taken by Regional partners, have at least maintained water quality because tributary nitrogen loads show no signs of increase. Nitrogen loads should continue to be monitored, and a more sophisticated trend analysis should be conducted to better understand trends.

Recommendations for Additional Actions — TRPA, in collaboration with federal, state, and local agencies, should pursue the strategies and actions identified in the Lake Tahoe TMDL with a goal of reducing tributary loading of sediment and nutrients, and achieving the interim target for Lake Transparency by 2026. TRPA's near-term implementation role should focus on program areas that it has the existing authority to lead: 1) accelerating implementation of its water quality BMP retrofit regulations including implementation of area-wide stormwater treatment strategies, 2) pursuing innovative redevelopment strategies that aim to accelerate water quality improvements, 3) reducing atmospheric sources of pollutants known to impact aquatic habitats, and 4) SEZ restoration and enhancement through the EIP (prioritized to tributary sources with the greatest pollutant load contribution). In addition, TRPA should work with the science community to develop quantitative pollutant standards for Tahoe Basin streams that take into account the large natural variation in yearly stream inflow.